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ABSTRACT

When the fossil fuels unit was first designed for Science 101 (the currently approved provincial guide for grade 10 science in Manitoba), Canadian support materials were very limited. Since students are asked to interpret data concerning energy consumption and sources for certain fossil fuels, the need for appropriate Canadian data became obvious. This document meets the need by: (1) providing some background information for teachers; (2) describing some activities and student-oriented information which are correlated to unit objectives; and (3) providing transparency masters which can be used to lead discussions or develop a new lecture. Topic areas in the overview section for teachers include effect of rate at which resources are used, factors affecting rate of resource use, supply and demand (oil/gas), octane numbers, and gasoline additives. Topic areas in student materials section include formation of fossil fuels, refining crude oil, burning fossil fuels, factors affecting the burning of fossil fuels, trends in fossil fuel use, and environmental effects. These materials can also be used for energy-oriented units in Physics 200, 300. (Author/JN)

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fossil fuels

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department of education

1982

FOSSIL FUELS

A Supplement to the Science 100, 101
Curriculum Guide

Manitoba Department of Education
1982

ISBN 0-86497-087-0

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INTRODUCTION

INTRODUCTION

When the Fossil Fuels unit was first designed for the Science 101 course, Canadian support materials were very limited. Since students are asked to interpret data concerning energy consumption and sources for certain fossil fuels, the need for appropriate Canadian data became obvious. Since the original development of the Fossil Fuels unit, additional energy-oriented units in Physics 200, 300 have been developed. This document attempts to meet the need for Canadian data and information related to the design of the units.

The document supports the teaching of the Science 101 unit "Fossil Fuels" by:

1. providing some background information for teachers;
2. describing some activities and student-oriented information which are correlated to objectives;
3. providing transparency masters which can be used to lead discussions or develop a lecture.

The physics units, "Energy Futures" and "Facts," are supported by the provision of more extensive and detailed information and graphs about resources, future alternatives, proposed scenarios about future energy needs and other data. The information in the transparency masters section can be used to:

1. develop decisions about future energy alternatives;
2. provide additional data for interpretive purposes;
3. develop lectures or discussions related to the design of the units.

OVERVIEW

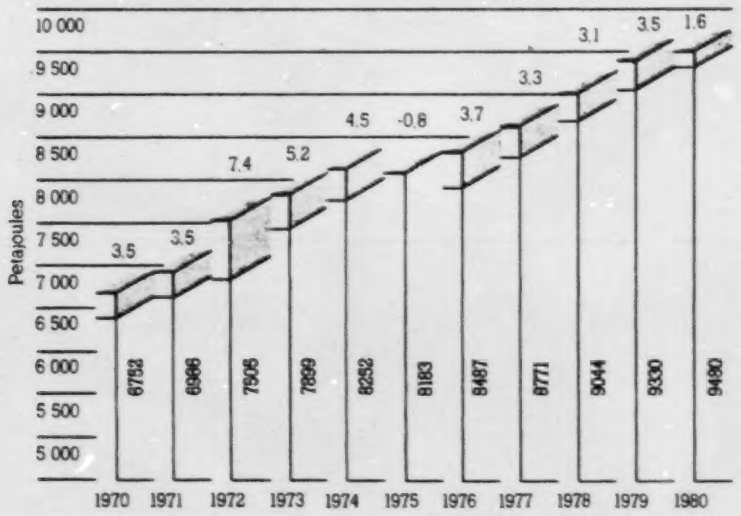
OVERVIEW

An important and extremely difficult question to resolve about the so-called "energy crisis" is, "How much lead time is available before major shifts are necessary to energy sources which are alternative to present fossil fuels?" Any questions about the future are difficult to resolve because of the variables present and the fact that the effects of different variables upon a question will change over a period of time. For example, some factors which affect the use of a finite resource (fossil fuels) include demand (affected by such variables as price), efficiency at which fuels are being used, location of resources, ease with which they can be acquired and the present status of the resource.

EFFECT OF RATE AT WHICH RESOURCES ARE USED

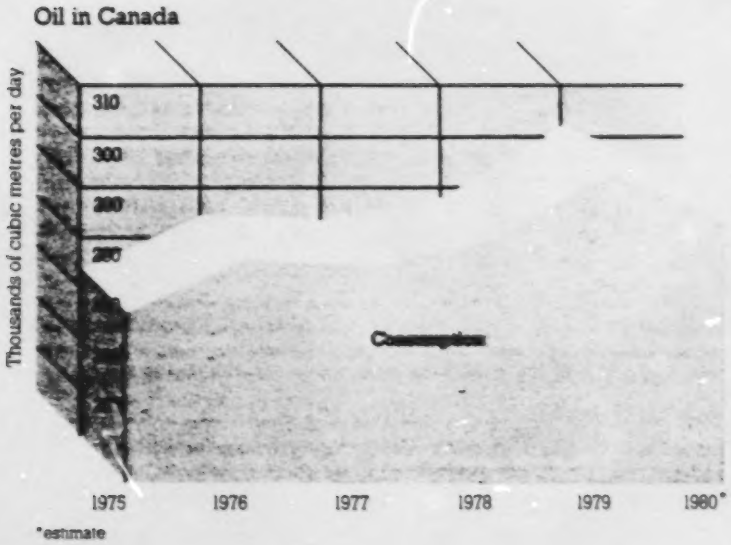
If growth rate is 5% per year, doubling time is 14 years; at 7%, doubling time is 10 years (i.e., money invested at 7% doubles in 10 years). Consumption of oil and gas has increased, and continued increases have important implications for future availability of resources. However, it is important to realize that there are dangers to extrapolating from the data on a graph.

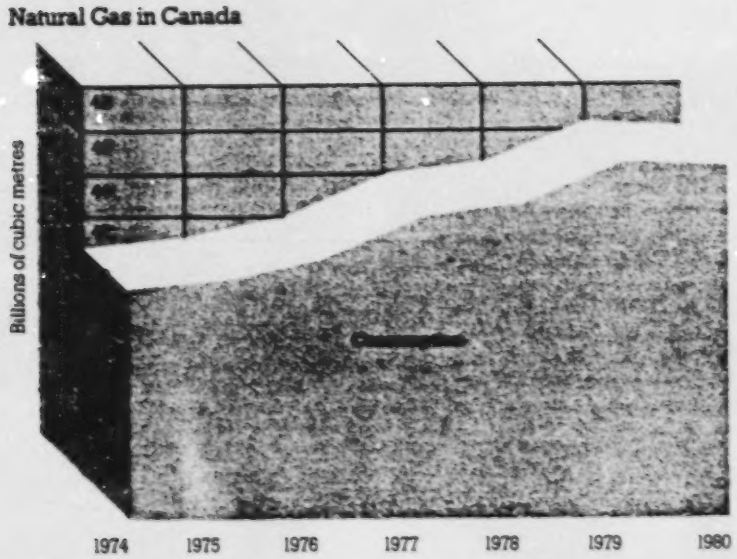
Total Energy Consumption 1970-80



Note Excluding biomass

Source: Energy Update, Energy, Mines and Resources Canada, Ottawa, 1981. Reprinted with permission.





Source: Energy Update, Energy, Mines and Resources Canada, Ottawa, 1981. Reprinted with permission.

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Oil

Billions of cubic metres

	1970	1975	1979	1980
World[1]				
Reserves	84 307	113 210	101 984	102 048
Production	2 657	3 099	3 618	n.a.
Canada[2]				
Conventional Reserves				
Initial in place	n.a.	2 192	2 264	2 287
Remaining	n.a.	1 092	866	806
*Production[3]	86	100	106	103
*Consumption[3]	85	100	111	109
*Imports[3]	44	50	37	35
*Exports[3]	44	52	33	28
Net Imports	0	−2	4	7

*Note: Figures include liquid petroleum gases.

[1]American Petroleum Institute
[2]National Energy Board (as of January 1)
[3]Energy, Mines and Resources Canada

Natural Gas

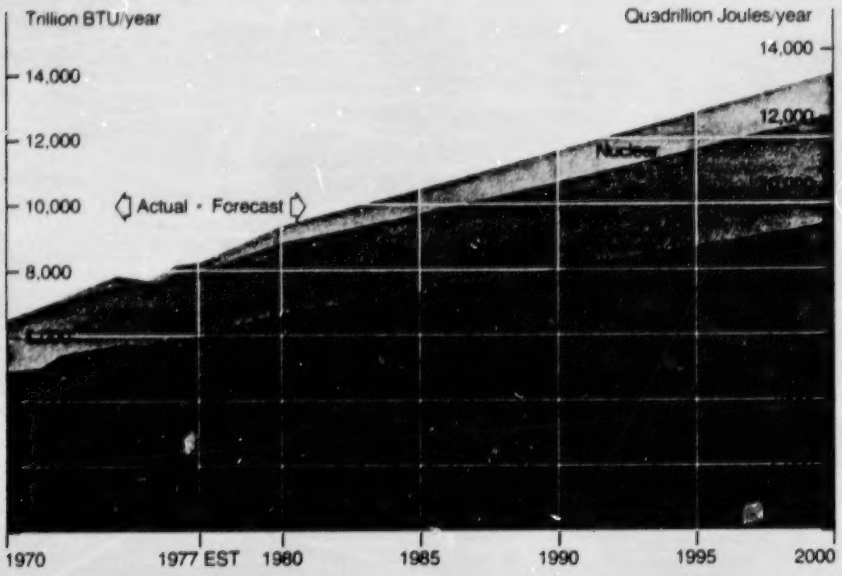
Billions of cubic metres

	1970	1975	1979	1980
World[1]				
Reserves	n.a.	72 107.0	70 716.0	72 892.0
Production	1 079.0	1 337.0	1 630.0	n.a.
Canada[2]				
Conventional Reserves				
Initial Recoverable	1 908.0	2 292.0	2 852.0	2 983.0
Remaining	1 560.0	1 623.0	1 906.0	1 956.0
Frontier Reserves	n.a.	n.a.	410.8	410.8
Production[3]	52.1	69.3	75.3	69.8
Consumption[3]	29.5	41.2	46.2	47.6
Exports[3]	22.1	26.8	28.3	22.5
Imports[3]	0.3	0.3	0.0	0.0
Net Exports	21.9	26.5	28.3	22.5

[1]American Petroleum Institute
[2]National Energy Board (as of January 1)
[3]Energy, Mines and Resources Canada

Source: Energy Update, Energy, Mines and Resources Canada, Ottawa, 1981. Reprinted with permission.

Canadian demand for primary fuels



Source: Our Petroleum Challenge - The New Era. Available from The Petroleum Resources Communication Foundation, 105, 309-2nd Avenue S.W., Calgary, Alberta, T2P 0C5. Reprinted with permission.

FACTORS AFFECTING RATE OF RESOURCE USE

One of the factors which affect the rate of commercial use of energy resources is the G.N.P. for a country. For example, the United States and Canada are among the top users of energy, whereas Ireland and Nigeria are among the lowest users of energy.

Efficiency of the conversion of energy is another factor which affects consumption. For example, during the period 1900-1970, the efficiency of power plants was raised from about 4% to about 30% by raising operating temperature and the size of generating plants. Similarly, railroad locomotives increased their efficiency partially by replacing steam with diesel-electric units. At the same time, despite some increase in the efficiency of car engines, the efficiency (in terms of passenger-kilometres) of automobiles decreased from 1940-1965 because of increased automobile weight and speed. This trend has been reversed recently. See Scientific American, September 1971, for more data concerning factors affecting resource use.

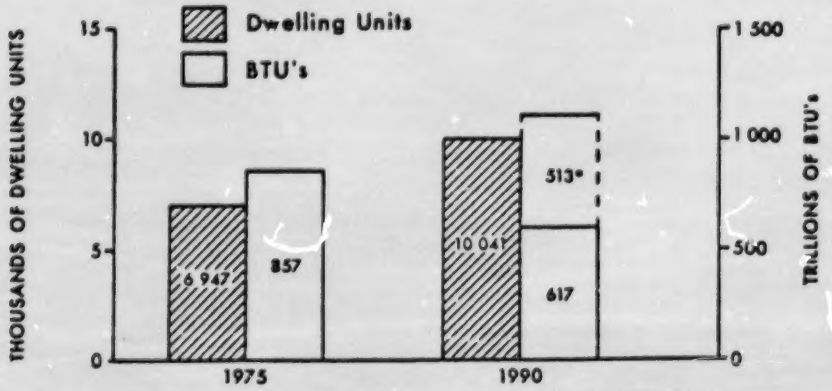
During the 1960s, plastics and aluminum replaced steel, and agriculture became more energy intensive.[1] The automobile uses a large quantity of the world's oil consumption and, except for the airplane, is the most relatively inefficient means of travel (in terms of energy use/capita).

---

[1] An interesting article about energy use in the food industry is "Energy Use in the United States Food System," from Lon Ruedisili and Morris Firebaugh (Eds.), Perspectives on Energy, Oxford University Press, Inc., 1978.

Studies of energy conservation measures suggest that the total energy requirements for residential space heating and automobiles could be reduced to amounts below that used in 1975. "Preliminary estimates indicate that it could be feasible to reduce the growth rate in energy to 2% per year on average, over the next 15 years, with minimal economic or social cost."[2] Some possibilities are illustrated in the following graphs.

Energy use for residential space heating.



* Savings attributable to improved furnace servicing (20%), new construction standards (31%), and retrofitting (49%).

Source: An Energy Strategy for Canada: Summary Policies for Self-Reliance, Energy, Mines and Resources Canada, Ottawa, 1976. Reprinted with permission.

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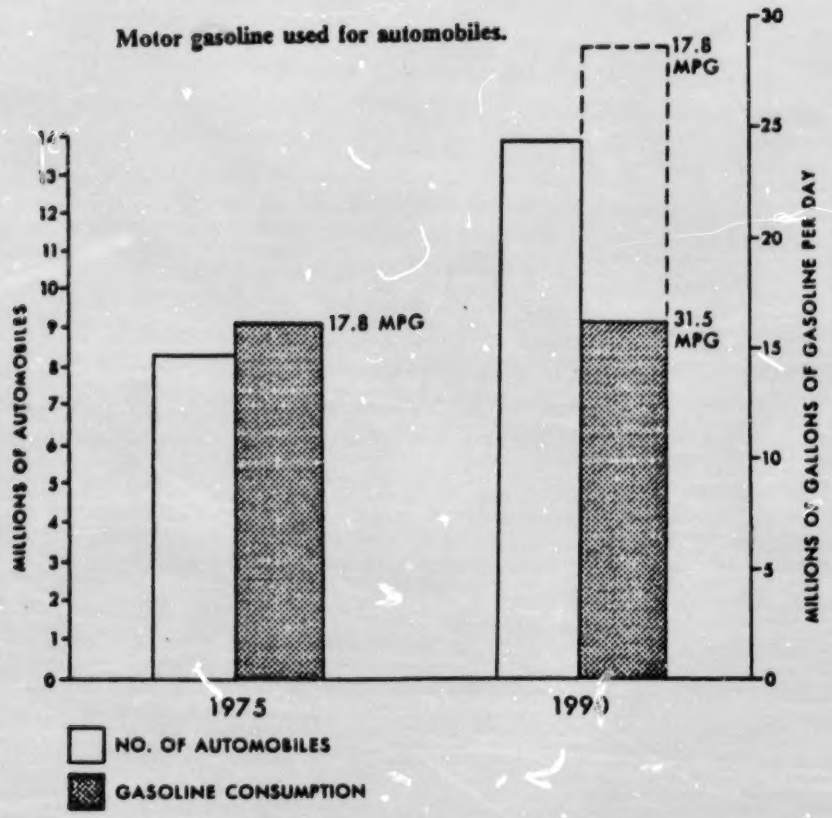
[2] An Energy Strategy for Canada: Summary Policies for Self-Reliance, Energy, Mines and Resources Canada, Ottawa, 1976, p. 20.

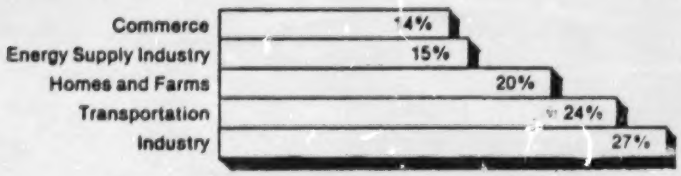


Source: An Energy Strategy for Canada: Summary Policies for Self-Reliance, Energy, Mines and Resources Canada, Ottawa, 1976. Reprinted with permission.

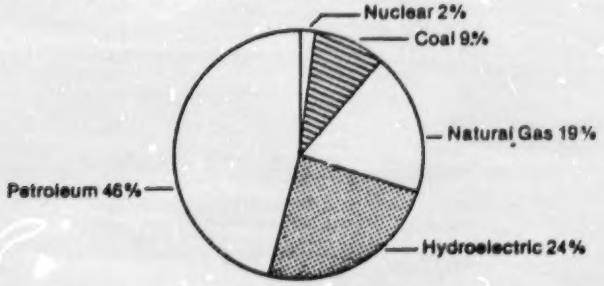
The following graphs indicate both consumers and present suppliers of energy in Canada. You may wish to display these graphs and suggest potential ways whereby energy use can be decreased within a sector.

ENERGY TODAY, YESTERDAY and TOMORROW

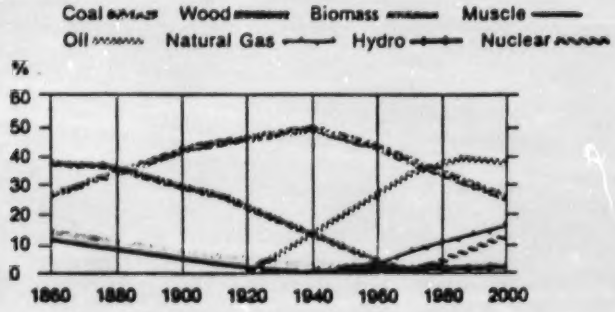
Consumers of Canada's Energy (1978).



Suppiier's of Canada's Energy (1978).



Major World Energy Sources Past and Present (with some projections for the future).



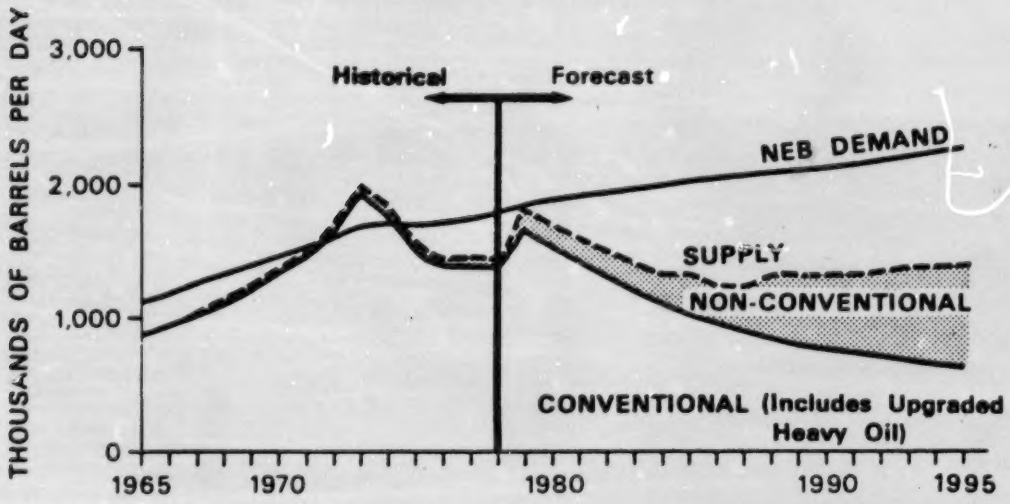
Source: Energy Management for the Future, Energy, Mines and Resources Canada, Ottawa, 1978. Reprinted with permission.

SUPPLY AND DEMAND - OIL AND GAS

Estimation of the future supply and demand for fossil fuels such as oil and gas is built upon a number of assumptions, including expected economic growth, costs of fuel, and expected development time for new technologies. This is illustrated by the following statement and graph from Canadian Oil and Gas Supply/Demand Overview (November, 1979), p. 20:

> These NEB demand and supply projections are simply one set of many possible outcomes. Over the last few years the base oil projections of the NEB changed considerably ....Most of the very large differences between the demand projections are the result of different economic and price assumptions. The differences on supply/producibility side, however, particularly for total crude oil, seem to reflect some of the swing in the perceptions...about the probable rate of development of Canada's recoverable reserves of non-conventional crude oil.

SUPPLY/DEMAND PROJECTIONS - OIL



Source: Canadian Oil and Gas Supply/Demand Overview, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

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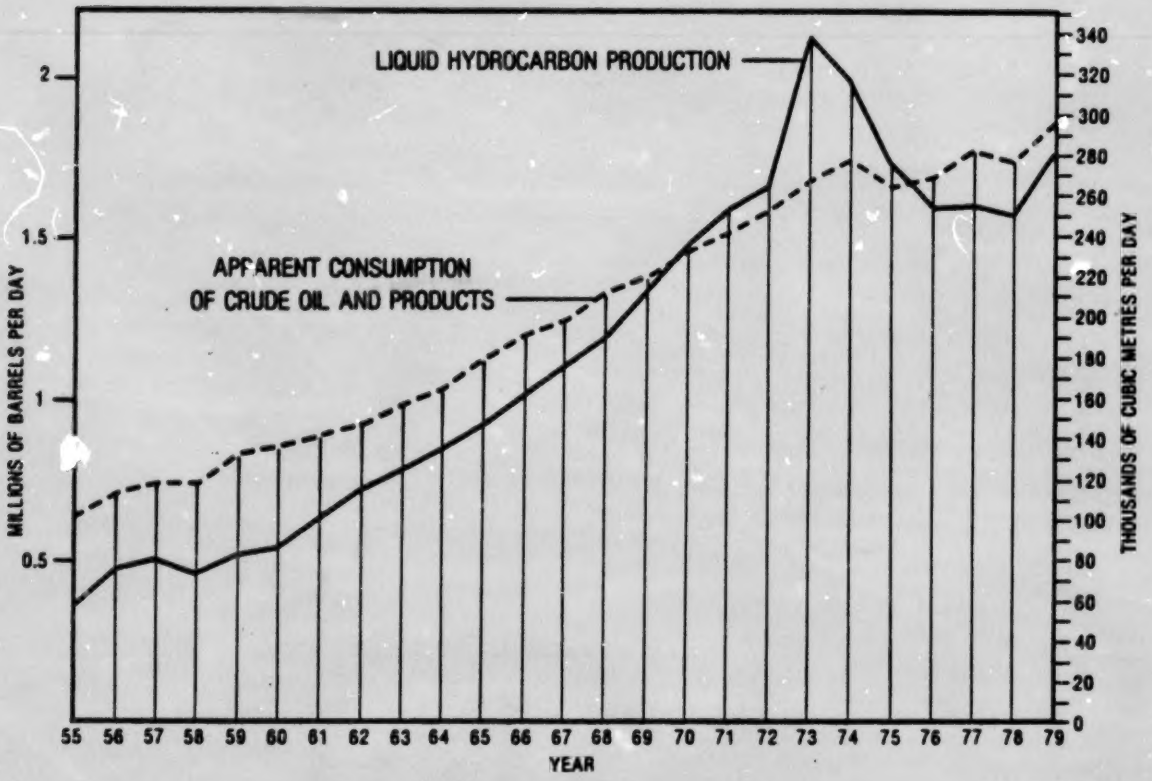
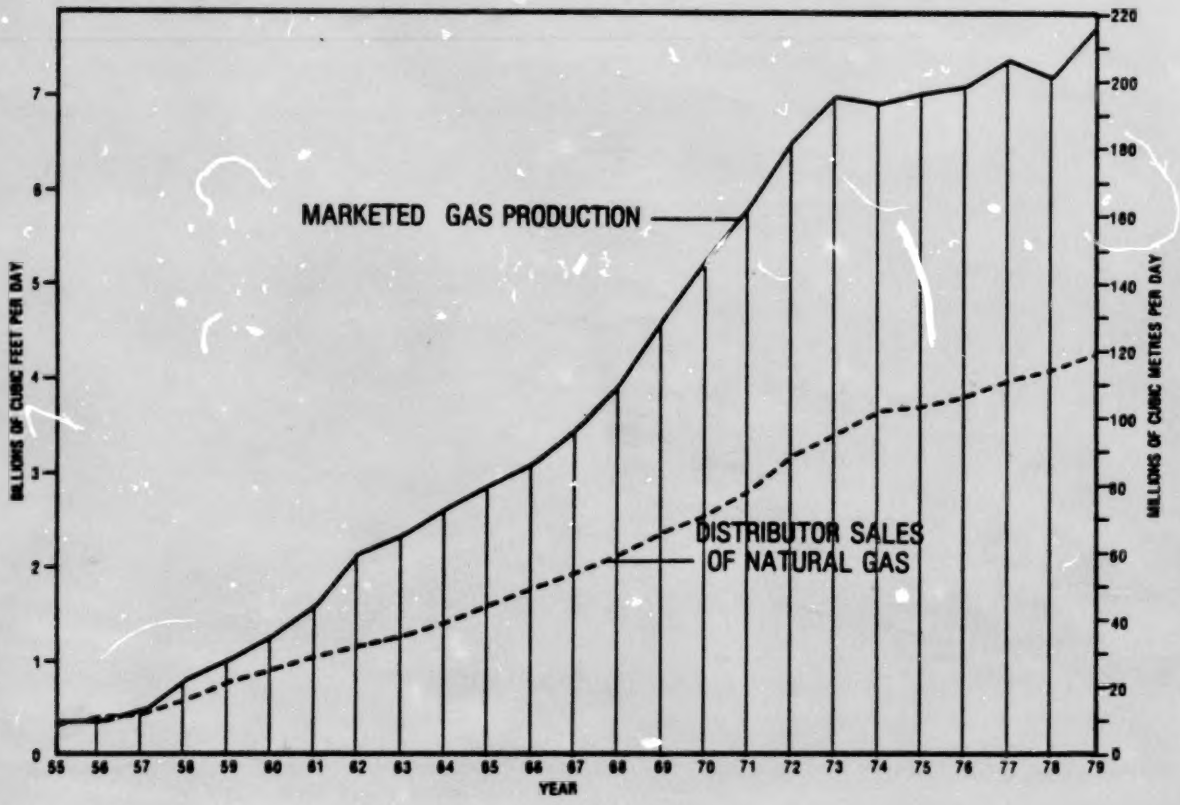
CANADA'S PRODUCTION AND CONSUMPTION OF PETROLEUM, 1955-1979



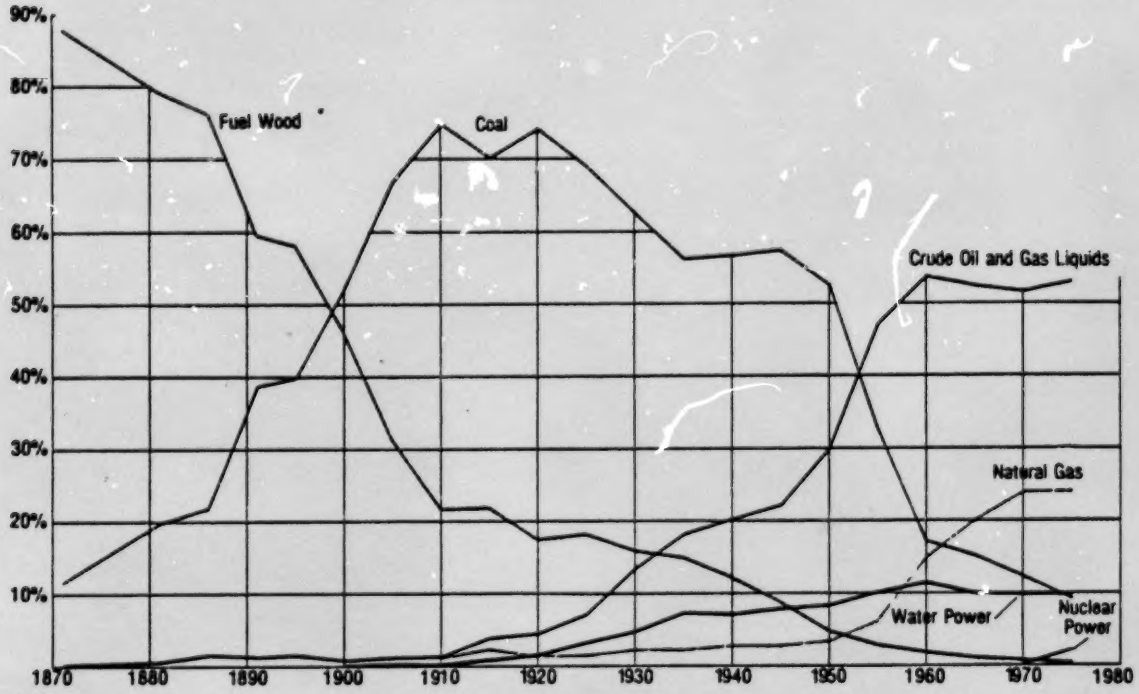
Source: Energy Alternatives: A Report by the Special Committee on Alternative Energy and Oil Substitution, Energy, Mines and Resources Canada, Ottawa, 1980-81. Reprinted with permission.

CANADA'S PRODUCTION AND CONSUMPTION OF NATURAL GAS, 1955-1979



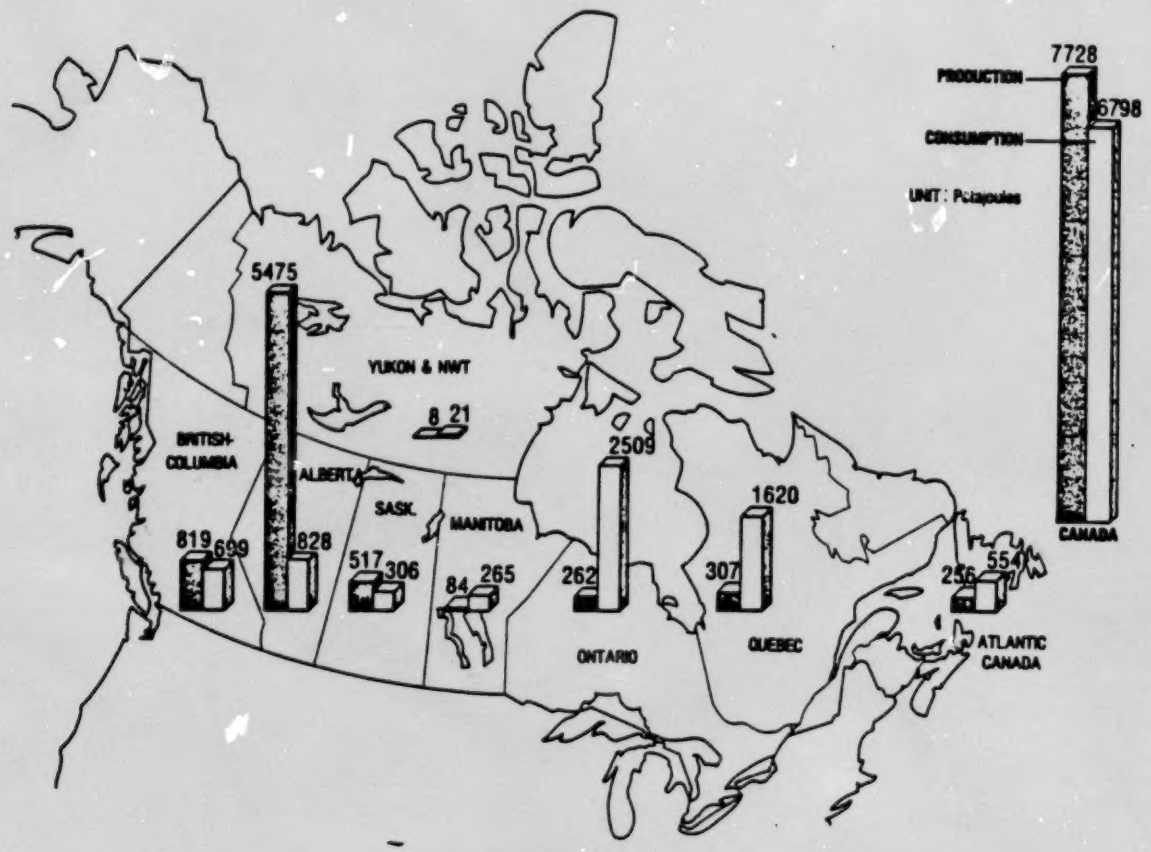
Source: Energy Alternatives: A Report by the Special Committee on Alternative Energy and Oil Substitution, Energy, Mines and Resources Canada. Ottawa, 1980-81. Reprinted with permission.

THE PRIMARY ENERGY MIX IN CANADA SINCE 1871



Source: Energy Alternatives: A Report by the Special Committee on Alternative Energy and Oil Substitution, Energy, Mines and Resources Canada, Ottawa, 1980-81. Reprinted with permission.

PRIMARY ENERGY PRODUCTION AND NET ENERGY CONSUMPTION BY REGION IN CANADA DURING 1978



Notes: [a] Data for Newfoundland, New Brunswick, Nova Scotia and Prince Edward Island are aggregated as Atlantic Canada for reasons of confidentiality in industry reporting. Energy statistics for the Yukon and Northwest Territories are also aggregated. Otherwise the regional breakdown is by province.

[b] Primary energy production refers to the energy extracted from a given region of Canada. We refer here to the production of crude oil (both conventional and synthetic), natural gas, natural gas liquids, coal, hydro-electricity and nuclear-electricity. Net energy consumption refers to energy actually consumed in a given region of Canada.

Source: Energy Alternatives: A Report by the Special Committee on Alternative Energy and Oil Substitution, Energy, Mines and Resources Canada, Ottawa, 1980-81. Reprinted with permission.

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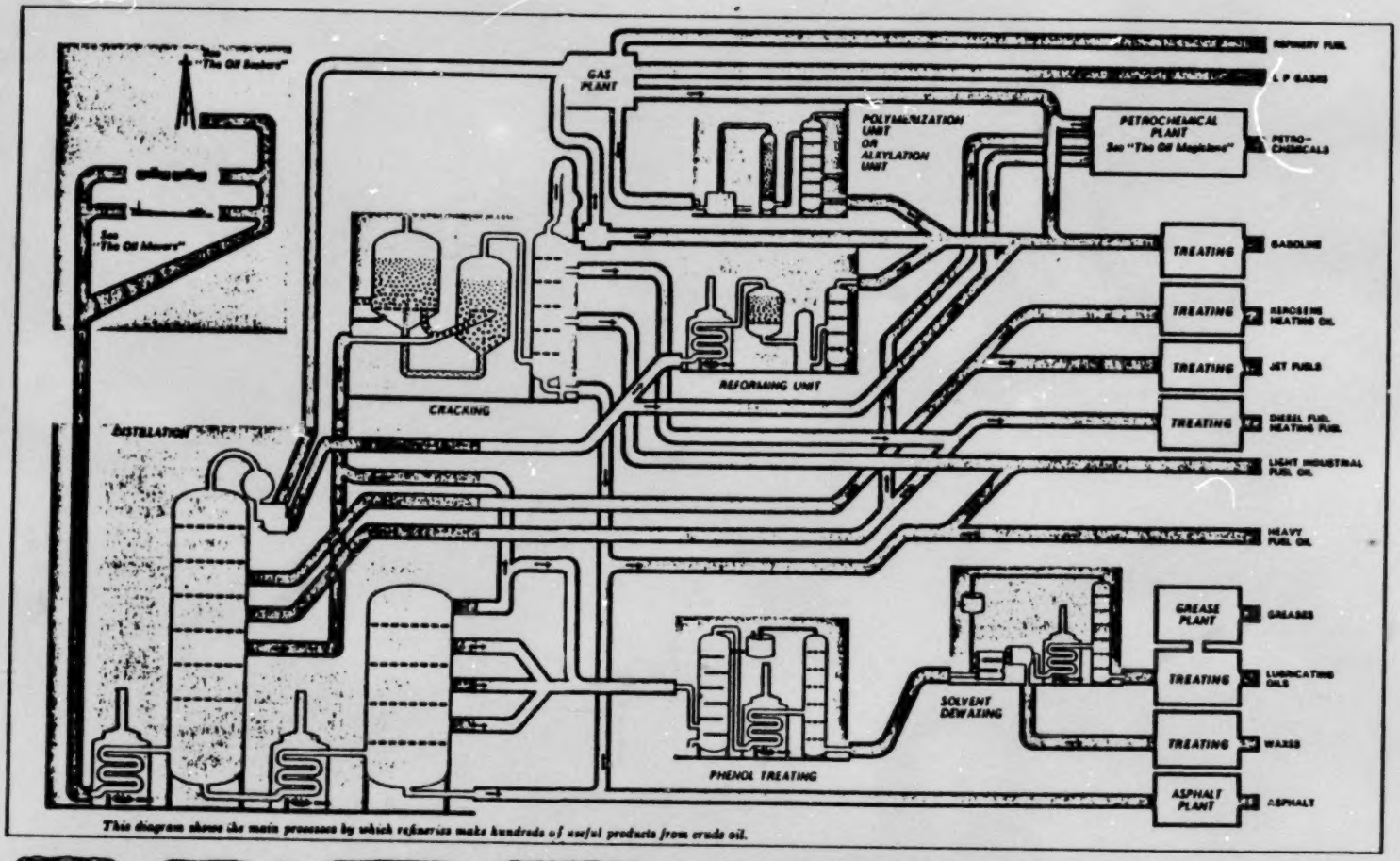
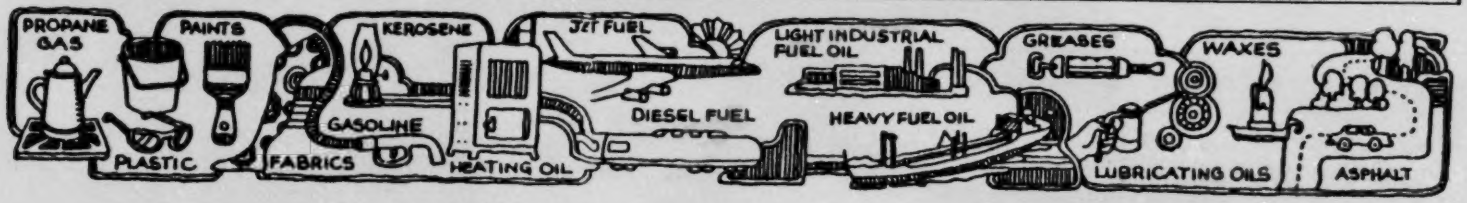




Source: All About Oil. Imperial Oil Limited. Out of Print. Reprinted with permission.

OCTANE NUMBERS

Octane numbers indicate the tendency of a gasoline to burn properly without knocking in an engine. The higher the number, the less the tendency to knock. Gasoline blends are compared to reference fuels of known octane numbers. For example, isooctane: 100 (octane number) and normal heptane is 0 (zero). Therefore, a gasoline with an octane number of 90 would behave as if it was a mixture of 90% isooctane and 10% heptane.

Regardless of octane number, gasolines have about the same energy content when burned completely. Energy losses are caused by incomplete burning and the effects of knocking. Using gasolines of octane numbers higher than necessary to prevent knocking is of little value.

GASOLINE ADDITIVES

Procedures for reducing knocking include: (1) using branched-chain and aromatic hydrocarbons that burn satisfactorily, and (2) adding anti-knock chemicals such as tetraethyl lead $(C_2H_5)_4Pb$, a toxic chemical.

Generally, additives control the rate of combustion in a chamber (slows down reactions). Dibromoethane is added to help remove the lead from the engine by forming lead bromide as a vapour.

Other chemicals, such as phosphorous compounds and boron compounds, prevent glowing particles from pre-igniting fuel. Boron compounds also prevent sulfur compounds in fuels from rendering tetraethyl lead ineffective. Dyes, anti-rust agents, anti-icing agents and other chemicals are added for specific functions.

STUDENT MATERIALS

These materials are correlated to objectives for "Fossil Fuels" in Science 101.

OBJECTIVE 1:	Describe how fossil fuels have been formed and possible technological reasons for limitations in supply.

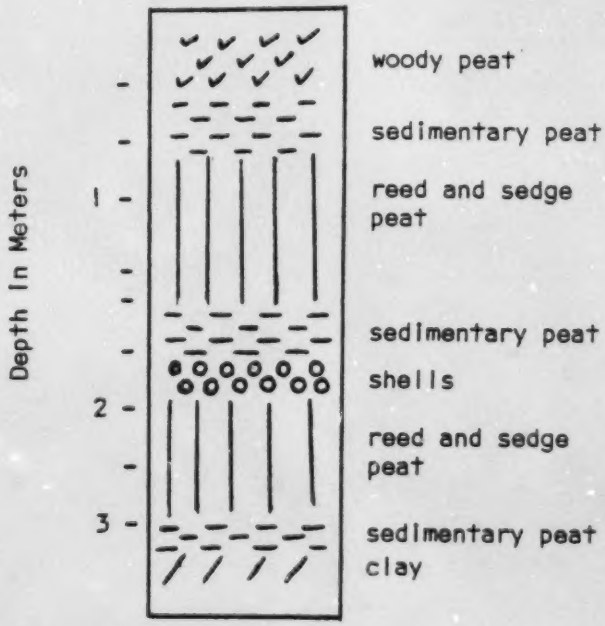
Note: Suggested student activities and background information about the formation of fossil fuels have been provided to enable teachers to use a variety of approaches to this topic.

FORMATION OF PEAT

> ... a great many horns, heads, bones of several kinds of deer, the horns of the antelope, the heads and tusks of boars, etc. are also found in it: and I have been told that some human bones have been found.
>
> John Collet, 1757

The above report describes the remains found in a peat pit in Berkshire, England and reflects the general view of peatlands as forbidding wastelands. Yet today, these areas may be important future reserves of raw material for agriculture, industrial gases and petroleum products.

Peat is a natural product, formed from the decomposition of plant materials. Conditions which seem to favour the formation of peat are absence of air through waterlogging, acidic content, and humidity. These conditions are found in marshes and bogs. Among the peat-forming plants are cattails, sedges, reeds and shrubs. It is belived that many of the peat deposits in the northern hemisphere were formed since the last Ice Age. Examination of the cross-section of a peat deposit suggests that different kinds of plants have helped to form different layers and that climatic and environmental changes may have occurred.



QUESTIONS

1. State the evidence that you have found to indicate that coal is formed in layers and under different amounts of pressure.

2. What conditions may have affected the production of different kinds of coal?

3. Why does some coal contain fern fossils?

Note: Sources of information about the formation of coal are:

1. Coal in Canada. Ottawa, Minister of Supply and Services, 1976.

2. Bielenstein, H.U., et al. Coal Resources and Reserves of Canada. Ottawa, Minister of Supply and Services, December, 1979.

3. Coal in Canada. The Coal Association of Canada, 1978. Available by writing #590, Three Calgary Place, 355-4th Avenue S.W., Calgary, Alberta, T2P 0J1.

FACTORS TO COMPARE AMONG COALS

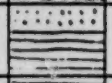
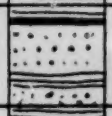
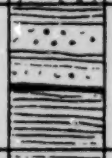
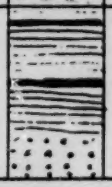
Coals are often classified or ranked on the degree of change from original plant material to carbon. Therefore, the amount of moisture and carbon are important characteristics of coal and will affect the thermal value (heat value per pound). Coal also contains quantities of undesirable substances such as sulphur, phosphorous and other elements (potassium, calcium as traces).

ORIGIN OF COAL

It is believed that coal was formed in large, shallow seas or swamps beginning about 200-250 million years ago.

Within these swamps were large ferns and horsetails which grew and died and, over a long period of time, accumulated layer by layer. The layers were covered by other debris, such as clay, which decomposed. Fossils and the placement of layers of clay present evidence to support this belief. See the following example.

Geologist's Log from Bore-Holes and Cores

Principal Horizons ft.	Log	seam sections and depths
12 coal seam 50		c 24" at 371'
100		
coal seam 150		c 72" at 111'
coal seam 200		c 36" at 195'
250		
coal seam coal seam 300		c 37" at 25.81' c 70" at 277'

shale sandstone

Ask students to describe the depth (height) of coal seams and their location below ground from the geologists' log. What kind of sedimentary rock is usally found near the coal layer? What does this imply about the origin of coal?

FORMATION OF COAL

Coal is one of the most abundant sources of fossil fuels in Canada. Coal reserves may be an important source of energy during your lifetime. The following investigation will provide students with some evidence about the formation of coal and some of the advantages and disadvantages of using coal.

Materials

hammer
bunsen burner
tongs
magnifying glass
chunks of lignite, bituminous coal, and anthracite
glass beaker
wire mesh (heat)
safety glasses
straight pin

Procedure

CAUTION:	USE SAFETY GLASSES WHEN BREAKING MATERIAL OR WHEN HEATING MATERIAL.

1. Cover your working area with paper towels or similar material. Use lab coats, if available.

2. Use a pin or similar material and attempt to scratch the different kinds of coals by applying similar pressure to each. Classify the coals from softest to hardest and shiny to dull.

3. Examine each type of coal by carefully breaking each piece with a hammer. Examine the pieces for evidence of:

   a) plant fossils;
   b) layering;
   c) impurities such as shale or specks and layers of sulfur.

4. Remove the paper covering from the workplace. Light a small piece of coal (about the size of your small fingernail) over the bunsen burner and a protective wire or asbestos gauze. Hold the glass beaker about 15 cm above the burning coal for about 15-30 seconds. What kinds of material seem to stick to the beaker?

5. Try lighting different kinds of coal. Are some easier to light than others?

VM%*	FC%*	CLASS	GROUP	CALORIFIC VALUE **	
				Btu per lb	MJ/kg
2	98	ANTHRACITIC(1)	META--ANTHRACITE		
			ANTHRACITE		
8	92		SEMIANTHRACITE		
14	86	BITUMINOUS(2)	LOW VOLATILE BITUMINOUS		
22	78		MEDIUM VOLATILE BITUMINOUS		
~31	69		HIGH VOLATILE A BITUMINOUS	14 000	32.6
			HIGH VOLATILE B BITUMINOUS	13 000	30.2
			HIGH VOLATILE C BITUMINOUS	11 500	26.7
		SUBBITUMINOUS(4)	SUBBITUMINOUS A(3)	10 500	24.4
			SUBBITUMINOUS B	9 500	22.1
			SUBBITUMINOUS C	8 300	19.3
		LIGNITIC(4)	LIGNITE A	6 300	14.7
			LIGNITE B		

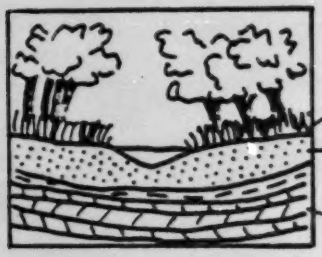
* Dry, mineral-matter-free basis.
** Moist, mineral-matter-free basis.
(1) Non-agglomerating; if agglomerating classified as low volatile bituminous.
(2) Commonly agglomerating.
(3) If agglomerating classified as high volatile C bituminous.
(4) Non-agglomerating.
VM: Volatile matter.
FC: Fixed carbon

SUMMARIZED CLASSIFICATION OF COAL BY RANK.

Source: Coal Resources and Reserves of Canada, Energy, Mines and Resources Canada, Ottawa, 1979. Reprinted with permission.

Swamp Environment

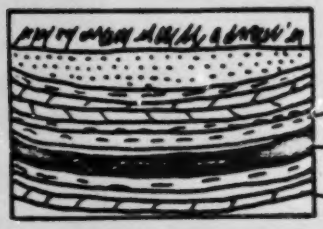
Vegetation Pools with Plants and Algae



Surface layers of leaves, twigs, branches and other plant material

Buried swamp material is partly decomposed, compressed into peat

Underlying rock

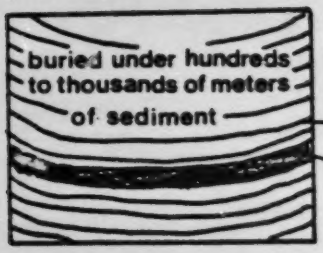


Shallow burial: Peat is compressed into brown coal

Overlying sediment

Brown coal

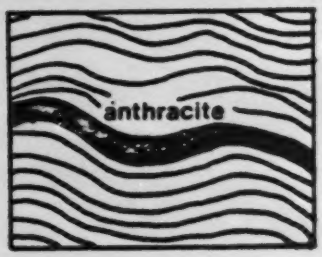
Overlying sediment



Deeper burial: peat is transformed into lignite if shallow, into bituminous coal if deeper

Underlying sediment

Lignite or bituminous coal



Further burial, compression, and deformation: pressure and heat change coal into anthracite or graphite

coal bed thins, becomes harder and brighter; heat value increases; carbon content increases; water, oxygen, and hydrogen content decrease

30

QUESTIONS

1. Why didn't the plants decompose before they could be turned into coal?

2. Describe the differences between lignite and peat, lignite and anthracite coal, in terms of formation, use and nature.

3. Describe our beliefs about how the Earth looked when coal first began to form.

OIL FORMATION AND RECOVERY

Note: Sources of information about the formation of oil and natural gas are:

1. Our Petroleum Challenge: The New Era. Available free from the Petroleum Resources Communication Foundation, T05, 309-Second Avenue S.W., Calgary, Alberta, T2P 0C5.

2. "Oil" (a film), Shell Film Library, Box 400, Terminal A, Toronto, M5W 1E1. This film introduces the theory of production of oil, location of oil, distillation and fractionating.

3. "The Fossil Story" (a film), Shell Film Library, Box 400, Terminal A, Toronto, M5W 1E1.

4. Oil and Gas: Their Origin, Production and Use. Available from Imperial Oil Limited, 111 St. Clair Avenue West, Toronto, Ontario, M5W 1K3.

5. "Once Upon a Barge" (Imperial Oil film). Available from Canfilm Screen Service Ltd., 583 Ellice Avenue, Winnipeg, R3B 1Z7.

6. Shell Canada Briefing Paper: Enhanced Recovery of Oil. Available from Shell Canada, P.O. Box 400, Terminal A, Toronto, M5W 1E1.

FORMATION OF OIL

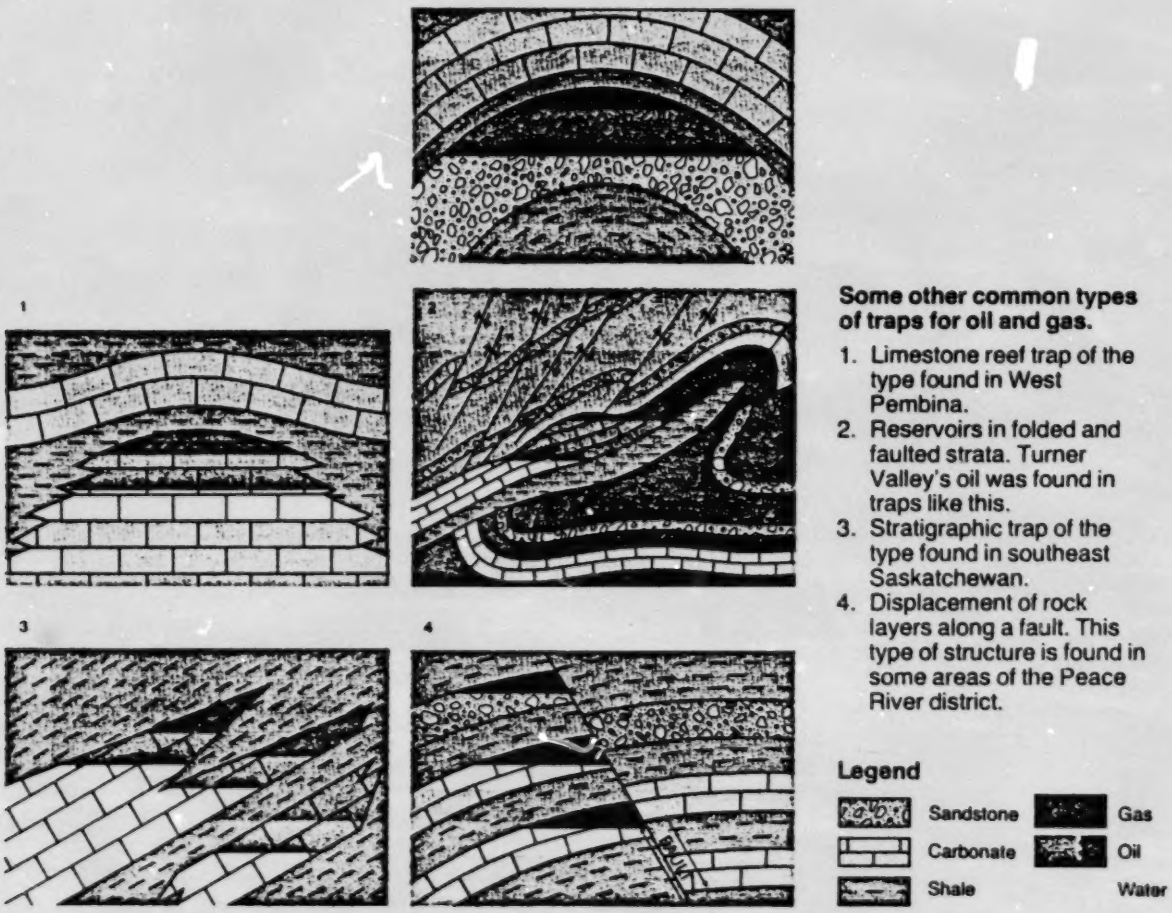
Formations of rock which contain concentrations of oil, gas and water are called reservoirs. The most common types of reservoirs are sandstones. Relatively young sandstones are more porous than older, more deeply buried sandstones. Many reservoirs occur in carbonate rocks--limestone and dolmite--which were formed originally from the bodies of shelled, marine life.

Focus on Energy Series. Available from the Canadian Petroleum Association, 1500, 633 Sixth Avenue S.W., Calgary, T2P 2Y5.

Focus on Energy: The Origin of Oil and Gas. 1979. Available from the Canadian Petroleum Association (see address above).

Focus on Energy: The Search. Available from the Canadian Petroleum Association (see address above).

It is believed that much of the oil began in the remains of many plants and animals that lived in the sea. As the layers of the remains were buried deeper and deeper, they were compressed. Heat, bacterial and chemical action gradually changed this organic matter (from living organisms) to gaseous and liquid hydrocarbons. Sedimentary deposits, which became rocks, often were tilted or folded as the result of earth movements. Where rocks were porous, the gas and oil could move slowly through it and the water in the pores. This movement or migration would stop if it reached a barrier of non-porous sedimentary rock (cap rock). Below are diagrams of typical oil reservoir formations.



Some other common types of traps for oil and gas.

1. Limestone reef trap of the type found in West Pembina.
2. Reservoirs in folded and faulted strata. Turner Valley's oil was found in traps like this.
3. Stratigraphic trap of the type found in southeast Saskatchewan.
4. Displacement of rock layers along a fault. This type of structure is found in some areas of the Peace River district.

Legend

Sandstone
Carbonate
Shale
Gas
Oil
Water

Source: Our Petroleum Challenge: The New Era. The Petroleum Resources Communication Foundation. Reprinted with permission.

ACTIVITY

Place the sand in a thin layer of oil (about 5 ml). Record what changes have taken place after 15 minutes and after 30 minutes. Leave for 24 hours, then observe again.

You may wish to test other types of rocks to find which is the best reservoir rock among your pieces.

You may wish to test different sandstones, shales, granite. An analogous situation is the use of a sugar cube and movement of a coloured liquid up the cube.

ACTIVITY: OIL CAP

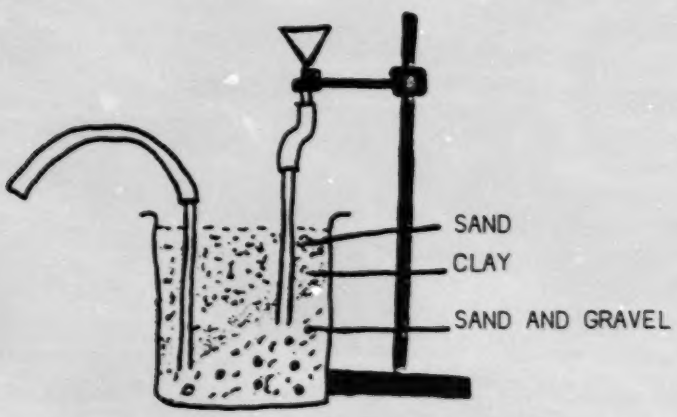
Materials

- 1 large beaker, at least 600 ml
- a half-and-half mixture of aquarium gravel and sand, enough to fill half the beaker
- 2 glass tubes, each about 17 cm long x 7 mm outside diameter and fitted through rubber bungs (each glass tube needs rubber tubing on one end, about 20 cm long)
- clay, about 350 g
- 1 filter funnel
- 1 stand and clamp
- sand to fill half the beaker
- dyed diesel fuel, 150 ml
- Sudan IV dye or similar dye

Set up the oil trap as shown. Be sure the clay forms a tight seal against the glass sides of the beaker. This can be tested by blowing down the tube while sealing off the other end before oil is added. This structure is similar to a fault trap.

Connect the filter funnel to the top rubber tube and clamp it in position. Pour in the 150 millilitres of dyed diesel fuel. The dyed fuel represents the oil.

You may wish to test different sands. Movement is slow through the sand. The model can be set up at the side of the room for a week.



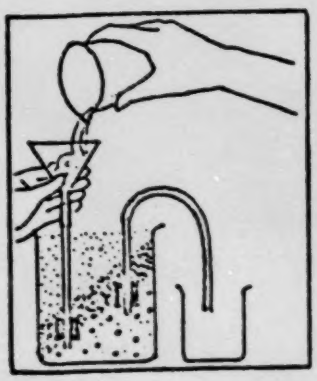
RECOVERY OF PETROLEUM

Most oil found underground has natural gas dissolved in it under great pressure. Water, which is underneath the oil in the trap, pushes up against the oil. When a bore hole is placed into the trap, the natural pressure is released and forces both oil and natural gas to the surface. Depending upon the amount of natural gas, water and other factors, this natural pressure allows recovery of about 15% of the oil in the trap because as the oil and gas is released, the natural pressure lessens. Other means such as pumping, or injecting water into the oil formation or trap, are used to increase the recoverable amount of oil.

ACTIVITY

Materials:

- your oil trap
- 1 beaker of water
- 2 empty beakers, each 250 ml
- paper on tables for cleaning up



Gas Drive

Blow air down the upper tube, which serves as the air injection tube. Direct the rubber tubing from the other glass tube into the beaker. See how much oil you can recover.

If you blow too hard, you may lift the whole clay plug. If this happens, hold it down with your hand. Any leaks that form in the clay must be repaired or the recovery will not work.

Record your observations on the recovery. Comment on how well it worked.

Water Drive

Pour the oil back into the trap through the filter funnel into the lower tube. Then, slowly run in water through the filter funnel into the lower tube. Direct the rubber tubing from the upper tube into an empty beaker.

Record your observations. Comment on how well the recovery worked.

Discuss the two processes with other students. Did one work better than the other? What were the main reasons why you could not recover all the "oil?"

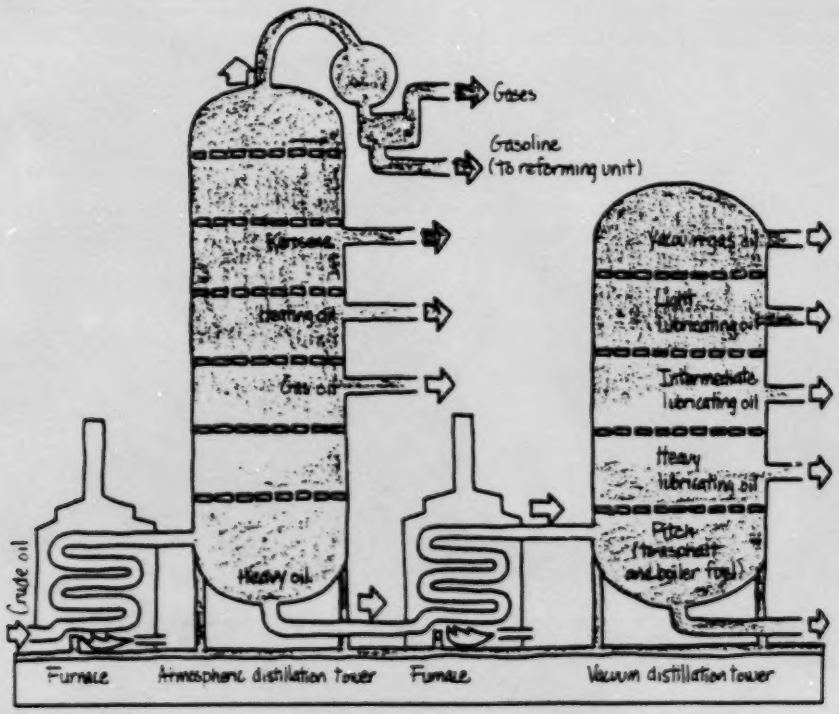
You may wish to do additional tests with your oil trap to obtain more information. Compare the structure of the model with underground structures.

OBJECTIVE 2: Describe the processes of fractional distillation and catalytic cracking that are used in refining crude oil.

Note: Sources for the above objective are:

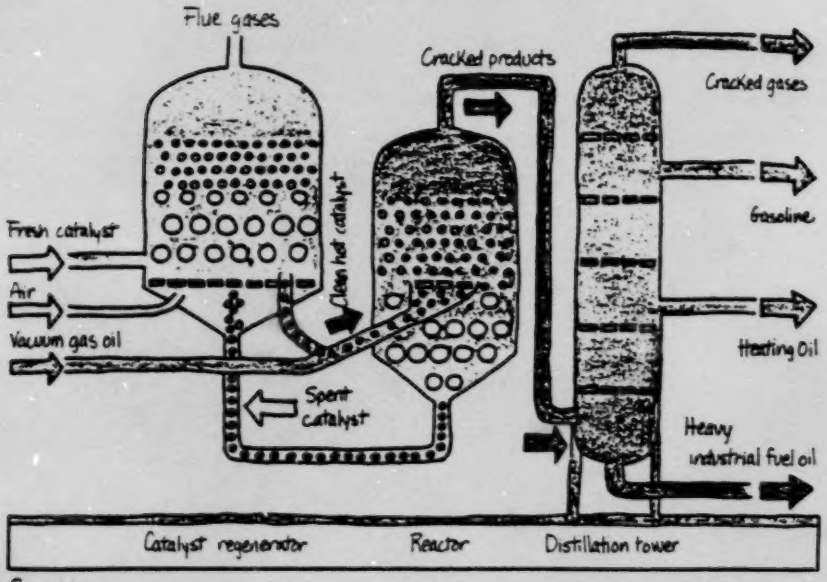
1. ISIS: Fossil Fuels.
2. Oil and Gas: Their Origin, Production and Use. Available from Imperial Oil Ltd., 111 St. Clair Ave. W., Toronto M5W 1K3.
3. Focus on Energy: Refining, Distribution and Marketing. Available from Public Affairs Department, Canadian Petroleum Association, 1500, 633 Sixth Avenue S.W., Calgary, Alberta, T2P 2Y5.

Crude oil is a mixture of many different compounds. Most of the compounds are liquids; however, some are gaseous or solid at ordinary temperatures. The substances boil and condense at different temperatures. A furnace, for example, starts to boil at about 200°C and its vapours condense at temperatures below 200°C. These different condensation temperatures are used to separate the crude oil into "fractions" by the process of distillation.



Distillation

Source: Oil and Gas: Their Origin, Production and Use. Imperial Oil Limited, 1979. Reprinted with permission.

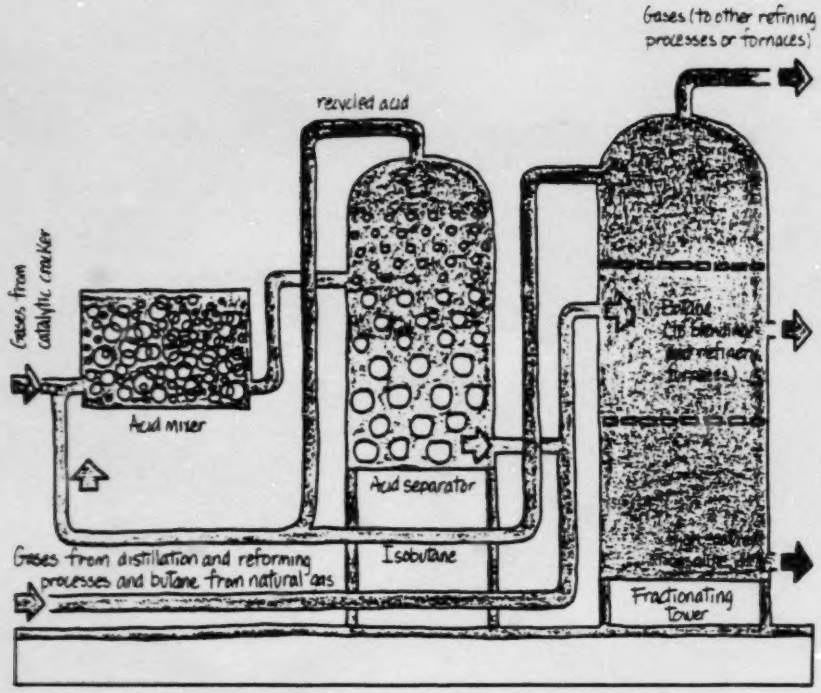


Cracking

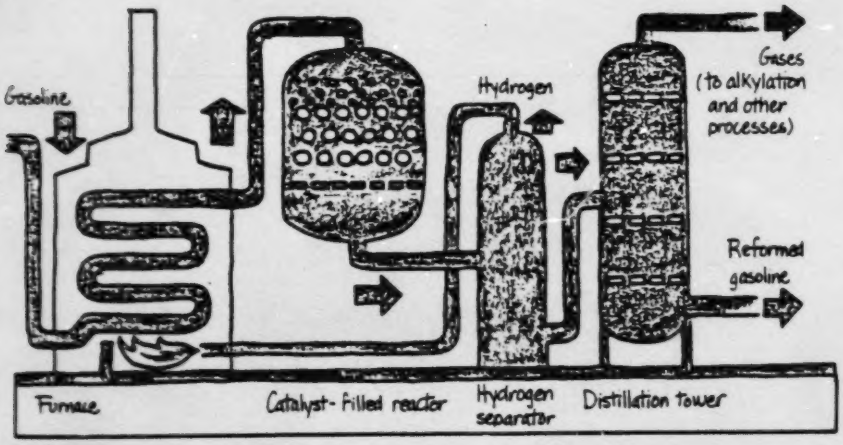
Source: Oil and Gas: Their Origin, Production and Use. Imperial Oil Limited, 1979. Reprinted with permission.

Heavy oil can be converted to mixtures containing a number of lighter or different molecules. One of the main conversion processes is cracking-heating a fraction under pressure and with a catalyst.

Another conversion process is alkylation. In this process, some gases are passed over a catalyst and the molecules join to make other molecules, which can be used in gasoline. Reforming is a process that changes the molecular structure of molecules into higher octane molecules by reacting the molecules in the presence of a catalyst.



Alkylation process



Reforming

Source: Oil and Gas: Their Origin, Production and Use. Imperial Oil Limited, 1979. Reprinted with permission.

OBJECTIVE 3:	Identify the two major products and give five others that result from the burning of fossil fuels. Identify carbon as a product of burning fossil fuels in an oxygen deficient environment. Describe the chemical reaction for burning short-chain fossil fuels; e.g., methane.

Note: Sources are:

1. ISIS: Fossil Fuels.

2. The Car Mileage Book, Energy, Mines and Resources Canada, Ottawa, 1977.

Gasoline grades are different in that each grade contains different mixtures of substances. This difference causes the grades of gasoline to burn at different rates during the power stroke. The total number of cycles for the operation of a 4-cycle engine are shown in the following diagrams.

INTERNAL COMBUSTION ENGINE

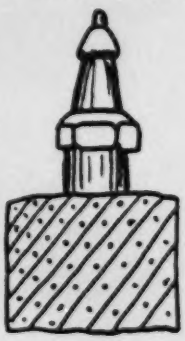
An internal combustion engine is one that produces power by burning inside it. The burning of gasoline releases stored energy and provides the engine with the ability to do work. Let's look at a simplified version of that engine to see how it converts that stored energy into forward motion. To simplify that task, we'll break the engine down into systems.

THE POWER

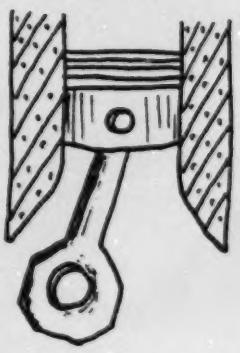
Imagine an enclosed cylinder with a mixture of air and gas inside. If that mixture were to be ignited, the cylinder would explode. The engine is capable of controlling that explosion through the use of valves, which allow gas to enter and exhaust to escape, and a piston which, driven by the expansion of gases, translates this energy into motion. In most engines, each cylinder contains:

1 exhaust valve
1 intake valve

1 spark plug



1 piston with
connecting rod



If the gasoline ignites at the wrong time and the burning is uneven, the engine will knock.

Each connecting rod connects the piston to the crankshaft. This crankshaft is the "backbone" of the engine. It is rotated at thousands of times per minute by the up-and-down motion of the pistons.

4-STROKE CYCLE

Each up-and-down motion of the piston is called a stroke. Most, if not all, automobile engines require 4 strokes to complete one cycle.

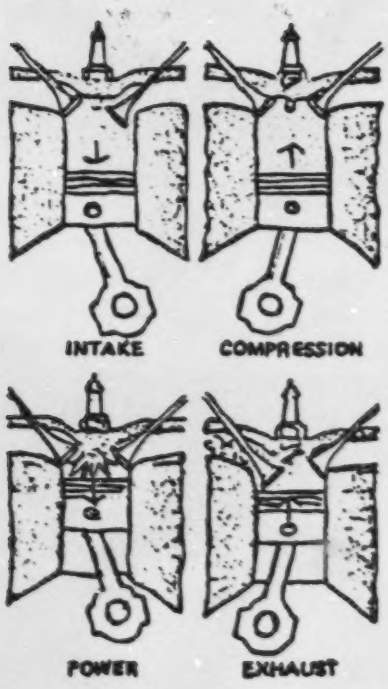
Each series of 4 strokes results in 2 revolutions of the crankshaft. This cycle proceeds as follows:

Intake: The intake valve (which allows the gas to enter the combustion chamber) opens and the piston moves down, drawing in the air-fuel mixture (see fuel system).

Compression: Both valves are closed and the piston moves up to compress the air and gas mixture in the combustion chamber.

Power: With both valves still closed, the piston up, and the air and gas mixture compressed, the spark plugs spark, igniting the fuel and causing a type of explosion, which forces the piston back down.

Exhaust: As the piston begins its journey back up, the exhaust valve opens and the piston pushes the burnt gas out. Then, the intake valve opens and the piston draws in the air-fuel mixture and the cycle begins again.



These strokes occur thousands of times per minute. The connecting rod transfers this up-and-down motion of the piston to the rotary motion of the crankshaft. This action is similar to the action of your legs as they pedal a bicycle.

This, then, is a very simple explanation of how one piston works to move your car. There are, of course, many different methods of achieving this end result and different methods of opening and closing the valves. However, there is always a "camshaft" which spins along an axis parallel to the crankshaft and is turned by the crank. The camshaft opens and closes the valves at the precise moments necessary for the entry or the release of gases.

Source: The Car Mileage Book, Energy, Mines and Resources Canada, Ottawa, 1979.

GASOLINE MIXTURES: THE CONTROL OF BURNING RATE

Two methods are used to control the burning rate of gasolines:

1. changing the mixtures of the hydrocarbons in the gasoline (hydrocarbon-compound of carbon and hydrogen only)

2. adding the substances

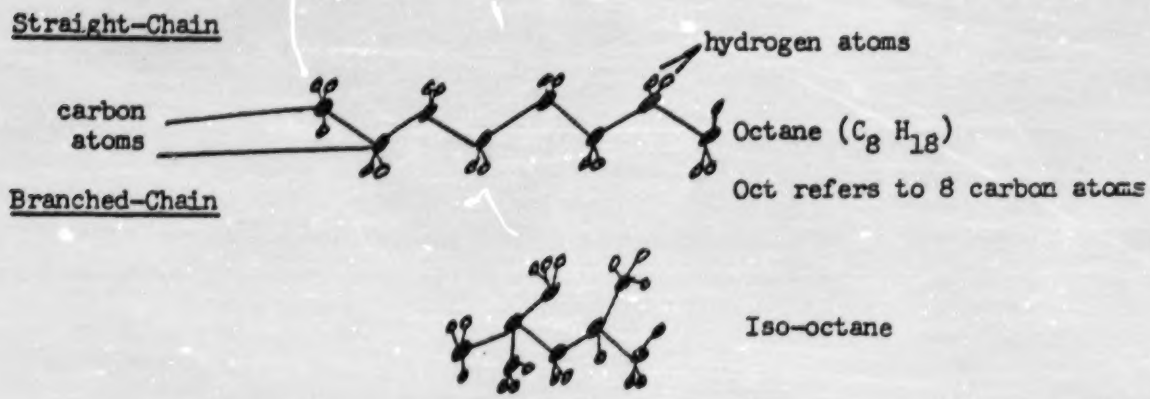
40

CONTROLLING THE MIXTURES

Hydrocarbons exist in two forms:

1. straight-chain
2. branched-chain

The figure below shows an example of hydrocarbon molecules in two forms.



Count the number of carbon and hydrogen atoms and compare the chemical formula of the hydrocarbon molecule with octane's formula. How are the molecules different from each other in the way the carbon atoms are joined to each other?

Straight-chain hydrocarbons burn faster than branched hydrocarbons. Why might it be more difficult for oxygen to join with the carbon in branched hydrocarbons than with straight-chain hydrocarbons?

One of the best non-knocking gasoline molecules is isooctane. Pure isooctane is used as a standard for comparing blends of gasoline, and is given an octane number of 100.

A mixture of isooctane and other gasoline molecules, such as 90% isooctane and 10% heptane, has a octane rating of 90. A mixture of gasoline and tetraethyl lead, with burns like the mixture of isooctane and heptane, has an octane rating of 90. The kinds of gasolines are blended according to the design of the engine or to prevent certain kinds of pollution (e.g., unleaded is made to prevent pollution and to have no effect on the catalytic converter).

OBJECTIVE 4: Describe how chemicals control burning rate, how octane numbers and gasolines differ, and relate these differences to eveness of burning. Describe how pollutants from car exhaust can be reduced by catalytic converters.

USING ADDITIVES

Another method of controlling the burning rate is by adding substances such as tetraethyl lead.

ACTIVITY OR DEMONSTRATION

Dip a paper strip into a borax solution (about 4 g of borax/L of water). When dried, compare burning rate to that of an untreated paper strip. The effects of different strengths of borax solutions could be compared.

CAUTION: FUMES - USE FUME CUPBOARD

Typical gasoline grades are shown in the diagram below. Octane ratings may vary or change. Could you use unleaded gasoline (as stated below) in a car which uses premium gasoline? What might be the effects on power and knocking?

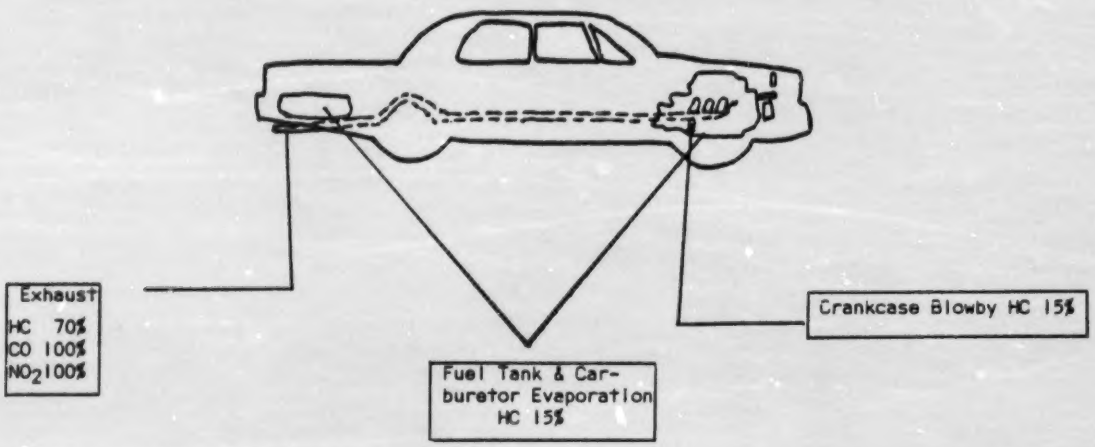
Note: Sources for information are:

1. ISIS: Fossil Fuels.
2. "Air," Shell Oil film (general information - also deals with proposed standards for waste emissions).

AUTOMOBILE WASTES

The gasoline burned by the internal combustion engine is composed of various sizes of hydrocarbon compounds. Smaller compounds are used in starting the engine, larger ones to keep it going during warm-up, and the largest are used at high speed. It is the uneven and incomplete combustion of these compounds that create carbon monoxide and hydrocarbon pollutants. Both are emitted primarily in the exhaust, although hydrocarbons also result from fuel tank and carburetor evaporation, as well as from crank case blow-by and leakage.

Nitrogen oxides are produced as a result of high combustion temperatures. Atmospheric oxygen and nitrogen combine in the engine to form nitrogen oxides that are emitted in the exhaust. The major technical problem in stopping effectively all automobile pollution results from the fact that increasing combustion efficiency, in order to reduce hydrocarbon and carbon monoxide emissions, increases the levels of nitrogen oxides formed. Although the technology to promote more complete combustion is available, there does not appear to be an immediate solution to the nitrogen oxide problem.



Source: The Economics of Clean Air, Report of the Administrator of the Environmental Protection Agency to the Congress of the United States, Washington, U.S. Gov't Printing Office, 1971, p. 3-3. Reprinted with permission.

The source of lead pollution from the automobile is the particulate matter emitted in the exhaust. Particulate matter consists of carbonacious material, salts and oxides of iron and lead, and droplets or particles of hydrocarbon materials. Lead compounds constitute about 80% of the particulate matter.

The level of emissions of carbon monoxide, hydrocarbons, and nitrogen oxides from the automobile and other forms of transportation in 1969 are given by percentage in the following chart.

Source*	CO	HC	NO_x
Motor Vehicles	64.7	45.7	36.6
Other Forms of Transportation	9.0	7.2	10.5

SOURCE: Annual Report of the Environmental Protection Agency to the Congress of the Unites States. In Compliance with Section 202 (b) (4) Public Law 90-148, The Clean Air Act As Amended, July 9, 1971, p. 4-1.

* These figures are averaged over the entire U.S. and compared to all other sources of air pollution.

CARBON MONOXIDE

Carbon monoxide is a colourless, odourless, and poisonous gas. It dilutes rapidly in the atmosphere, but because it is created by the incomplete burning of almost any substance (including tobacco), it is accompanied by other pollutants and is used as an approximate gauge of air pollution.

Carbon monoxide is absorbed through the lungs, reacts primarily with the hemoglobin of the blood, and robs the body of oxygen. Some doctors contend that prolonged exposure to even low levels of carbon monoxide is dangerous to heart patients, because the heart must work that much harder to supply oxygen to the blood.

OBJECTIVE 5: Describe trends in the use of fossil fuels and identify fossil fuels in the greatest supply and least supply in Canada.

TRENDS IN THE USE OF FOSSIL FUELS

Canadian Oil & Gas Supply/Demand Overview, Energy, Mines and Resources Canada, November, 1979.

Background to a New Energy Strategy. Energy, Mines and Resources Canada, November, 1979.

Our Petroleum Challenge: The New Era. Available from the Petroleum Resources Communication Foundation, 105, 309-Second Avenue S.W., Calgary, T2P 0C5.

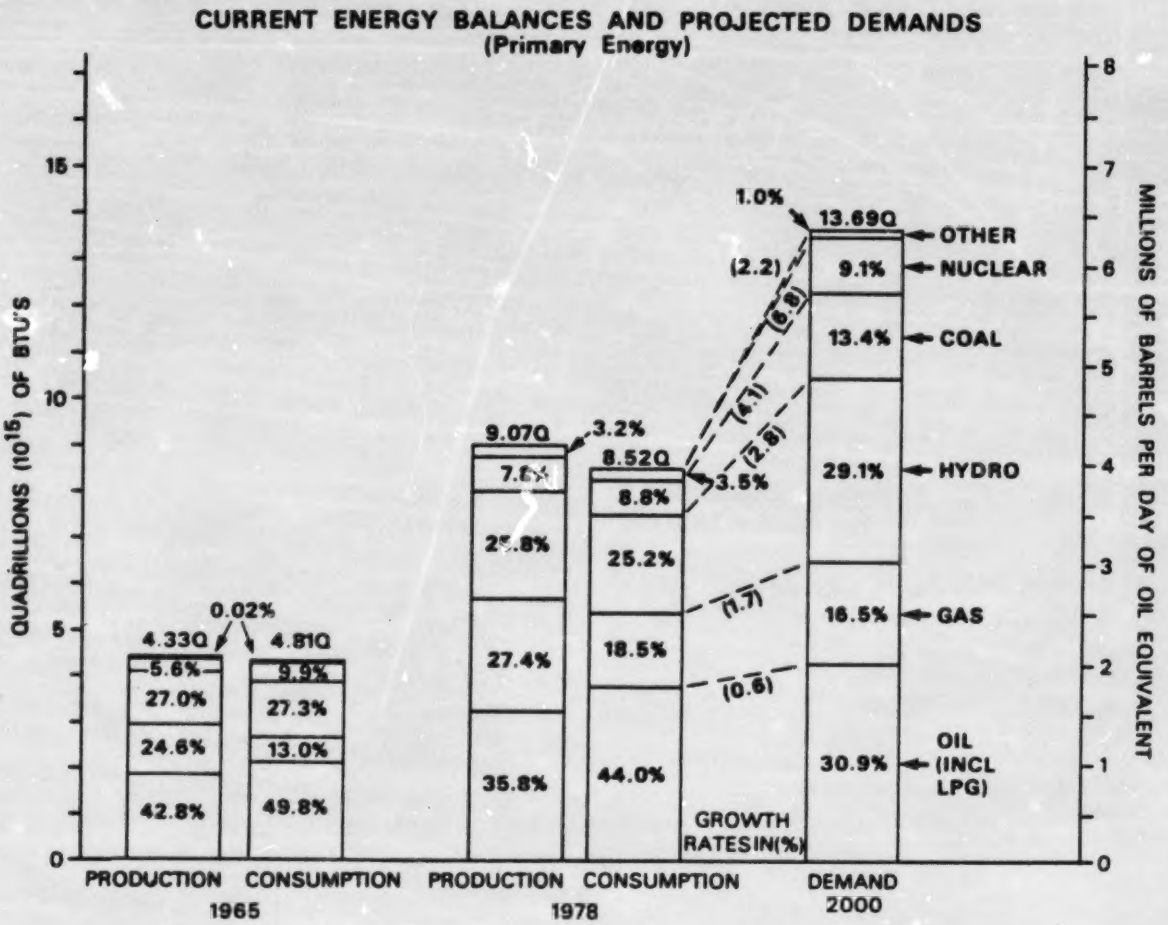
Coal in Canada. Available from The Coal Association of Canada, Suite 590, Three Calgary place, 355-4th Avenue S.W., Calgary, T2P 0C5.

Shell Canada Briefing Papers: World Oil and Gas in 1979. Available from Shell Canada, Public Affairs Department, P.O. Box 400, Terminal A, Toronto, M5W 1E1.

Energy Update 1981. Energy, Mines and Resources, Ottawa.

Energy Alternatives: A Report by the Special Committee on Alternative Energy and Oil Substitution. Minister of Supply and Services, Canada, 1981.

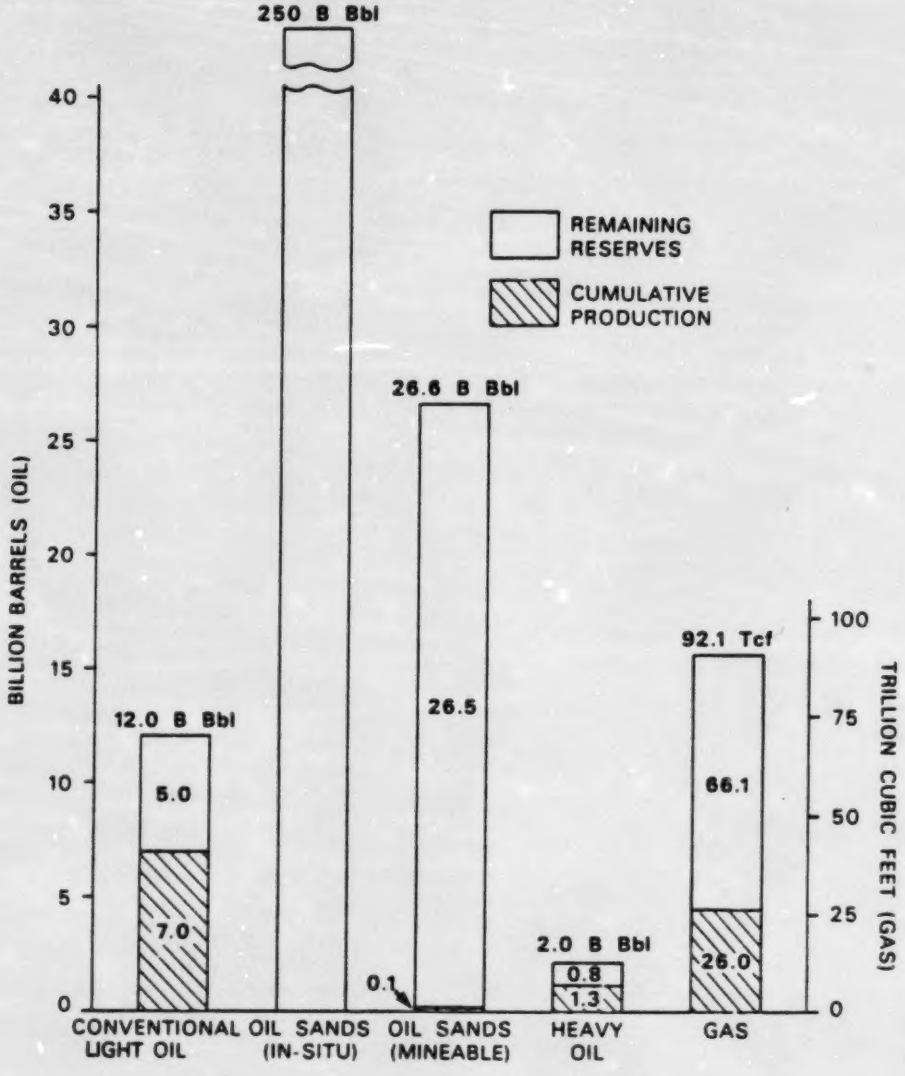
Increased populations, demands for consumer goods, and many other factors are affecting the amount of energy required by the world population each day. A graph follows which shows the use of different fuels and other sources of energy by Canadians over a period of time. Name two or three factors which contribute to our increasing use of fuels.



Source: Canadian Oil and Gas Supply/Demand Overview, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

What trend (in total energy demand) appears in the graph of the previous page? What are the trends in the use of petroleum? . . . of coal? What fossil fuel is expected to increase in use the most? What are some alternatives to fossil fuels which are predicted to increase in use? Why might these kinds of trends be predicted?

PROVEN RECOVERABLE RESERVES - OIL[1] & GAS[2]



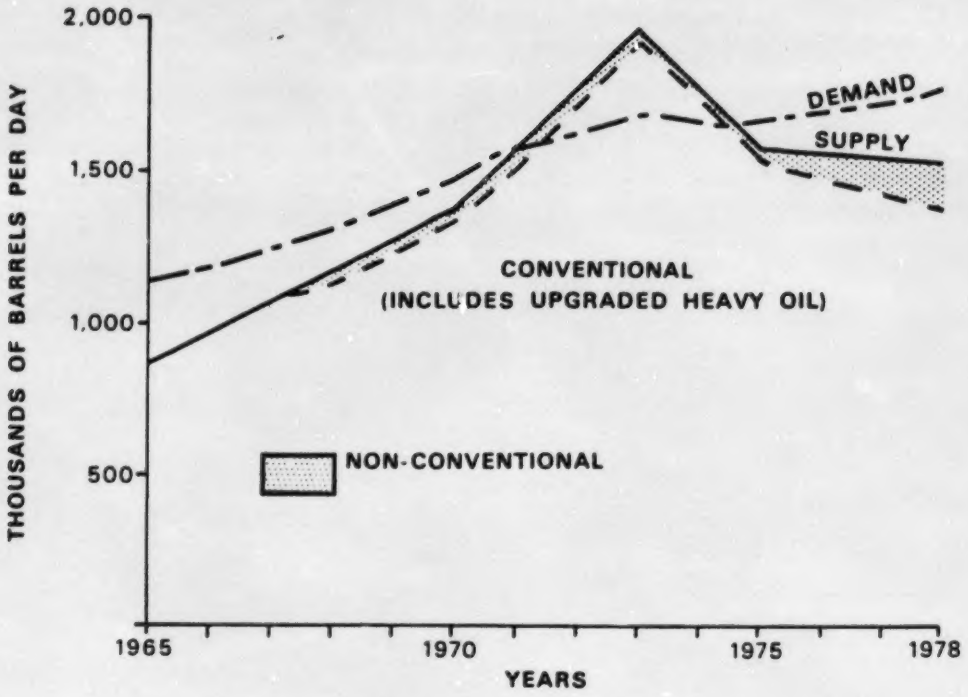
1 as of January 1, 1978
2 as of December 31, 1978

Source: Canadian Oil and Gas Supply/Demand Overview, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

SUPPLIES OF FOSSIL FUELS

Supplies of fossil fuels are limited. Deposits of fossil fuels are called reserves. Known deposits may be called "proven" reserves; however, with present technology, not all the fossil fuels can be obtained from reserves. Therefore, sometimes, "recoverable reserves" is used to indicate the amount of fossil fuels that can be recovered under present technologic or economic conditions.

HISTORICAL SUPPLY/DEMAND BALANCES FOR OIL

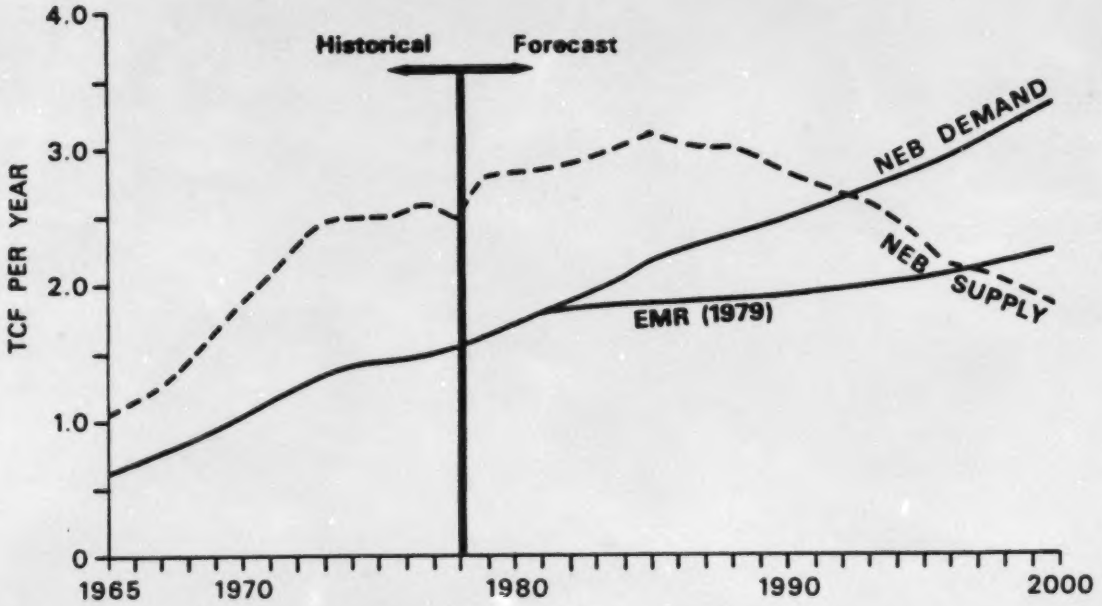


Source: Background to a New Energy Strategy, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

Where are our major potential reserves located?* Examine the graph on the previous page which compares supply (oil) and demand. What were the trends in Canadian crude oil productions between 1965-1973, 1973-1975 (supply) and 1975-1978? No major new discovery fields were located in recent times until the West Pembina field (Alberta)**. What is the trend in demand?

Examine the graph below to compare natural gas supply and demand. Compare supply in 1978 to 1965. Compare demand in 1978 to 1965. What is the projected supply for natural gas between 1980 and 1990? . . . past 1990? What are some possible reasons for these projections?

SUPPLY/DEMAND PROJECTIONS - MARKETABLE NATURAL GAS



Source: Canadian Oil & Gas Supply/Demand Overview, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

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* Refer to appendix for reserve-production ratios.

** See appendix for map showing location of West Pembina field and other resources such as heavy oil and tar sands.

Examine coal resources. Our coal production/consumption and resources are illustrated in the following tables. Approximately how long would presently identified sources of coal last at present consumption levels? What factors might affect this time?

Production, Exports, Imports and Consumption of Coal in Canada (Kilotonnes)

	PRODUCTION	EXPORTS	IMPORTS	CONSUMPTION
1970	15,063	3,984	17,121	28,200
1971	16,721	7,016	16,460	26,165
1972	18,787	7,777	17,485	28,495
1973	20,472	10,907	14,959	24,524
1974	21,268	10,774	12,400	22,894
1975	25,259	11,695	15,270	28,834
1976	25,476	11,708	14,622	28,390
1977 preliminary	28,394	13,030	15,134	30,498

SOURCE: Statistics Canada 1 kilotonne approximately equal to 2 short tonne.

Rank and Quality of Recoverable Coal (1977)[1]

Area	Rank[2]	Proximate analysis %[3] M	A	VM	FC	Sulphur %	Heating Value MJ/kg
Nova Scotia[4]	hvb	1-3	3-5	37-39	54-57	1-3	33-34
New Brunswick	hvb	2-5	20	31	44-77	7	26
Saskatchewan	lig	35	8	26	31	0.6	16
Alberta	sub	17-27	7-21	NA	NA	0.2-0.8	16-22
	h-mvb	1-12	10-27	22-34	42-50	0.3-0.6	24-25
	l-mvb	1-8	8-27	12-25	50-73	0.3-0.9	25-30
British Columbia and Yukon	lig	20	31	25	24	0.4	13
	h-mvb	2-8	12-24	19-30	47-61	0.3-0.4	25-33
	l-mvb	1-7	18-24	17-23	47-62	0.4-0.6	25-35

(1) RECOVERABLE COAL (Level 2) is that part of MINEABLE COAL (Level 1) that could be recovered as run-of-mine coal with current technology and at current market prices. The coal deposit must be legally open to mining, and the necessary infrastructure must be in place or could be amortized through coal sales.

(2) lig = lignitic; sub = subbituminous; hvb = high volatile bituminous; lvb = low volatile bituminous; mvb = medium volatile bituminous.

(3) Proximate analysis is the determination, by prescribed methods, of moisture (M), ash (A), volatile matter (VM), and fixed carbon by difference (FC).

(4) Seam samples - not run-of-mine coal.

NA = Not available.

Source: Coal Resources and Reserves of Canada, Energy, Mines and Resources Canada, Ottawa, 1979. Reprinted with permission.

50

OBJECTIVE 7: Describe how extracting and transporting fossil fuels may affect the environment.

Sources are:

1. Coal in Canada. Coal Association of Canada, 1978. Available from #590, Three Calgary Place, 355-4th Avenue S.W., Calgary, Alberta, T2P 0J1.

2. Coal in Canada. Energy, Mines and Resources Canada, Ottawa.

3. Our Petroleum Challenge: The New Era. The Petroleum Resources Communication Foundation, 105, 309-2nd Avenue S.W., Calgary, Alberta, T2P 0C5.

4. Shell Canada Briefing Paper: Protecting the Environment
Shell Canada, Public Affairs Department, Box 400, Terminal A, Toronto, M5W 1E1.

5. Films. Shell Film Library, Box 400, Terminal A, Toronto, Ontario, M5W 1E1.

a) "Load on Top" (Discharge of oil into the sea and means for preventing oil pollution)
b) "Oil Spill Research"
c) "Offshore"

6. Videotapes. Manitoba Department of Education (IMS), Winnipeg (about 20 minutes in length) The videotapes can be copied and sent to interested schools.

"Transportation"; "Athabasca Tar Sands"; "Northern Operations"; "Offshore Drilling"

7. Focus on Energy Series. Canadian Petroleum Association, 1800, 633 Sixth Avenue, Calgary, Alberta, T2P 2Y5.

: Transportation
: Frontier Oil & Gas
: Oil Sands and Heavy Oil

Environmental problems with coal occur during production and consumption. In production, the land at the site is disturbed to different degrees. Regraphing of land to approximately original levels and reseeding are some techniques used to reclaim land. At coal burning plants, the use of precipitators and low sulfur coals reduce some of the environmental effects of extracting energy.

PREDICTION OF RESOURCE AVAILABILITY - AN UNCERTAINTY

It is extremely difficult to predict future availability of resources. Factors such as rate of use, technological feasibility, ease of exploitation and many others affect prediction. However, M.K. Hubbert of the U.S. Geological Survey, Hewett and others have developed useful models for prediction. Teachers should refer to "Survey of World Energy Resources" in Ruedisili, L. and Firebaugh, M (Eds.), Perspectives on Energy: Issues, Ideas and Environmental Dilemmas (Oxford University Press).

Additional Reference Materials

Texts

Daniels, F. Direct Use of the Sun's Energy. Toronto: Ballantine Books, 1964 (ninth printing: 1980).

Energy Alternatives: Report of the Special Committee on Alternative Energy and Oil Substitution to the Parliament of Canada. Ottawa: Minister of Supply and Services, 1981.

Energy: The Fuel of Life. Encyclopedia Brittanica, 1979.

Rowland, W. Fuelling Canada's Future. Toronto: MacMillan of Canada, 1974.

Ruedisili, L. and M. Firebaugh (Eds.). Perspectives on Energy: Issues, Ideas, and Environmental Dilemmas. Don Mills: Oxford University Press, 1978.

Saperstein, Alvin. Physics: Energy in the Environment. Toronto: Little, Brown & Company, 1975.

Stoker, S. et al. From Source to Use: Energy. Agincourt: Scott, Foresman and Company, 1975.

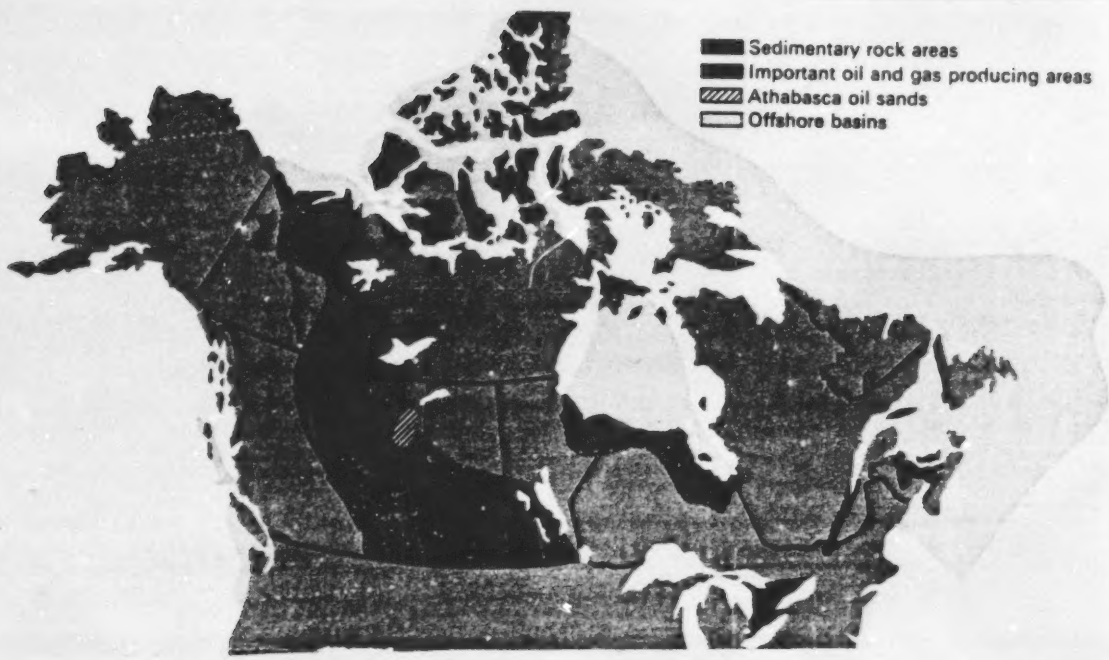
100 Ways to Save Energy and Money in the Home. Ottawa: Energy, Mines and Resources Canada, 1979.

Articles

Firebaugh, Morris. "Perspectives on Energy and the Environment." The Physics Teacher, February, 1977, pp. 78-85.

Levin, Franklyn K. "The Physics of Petroleum Exploration." The Physics Teacher, January, 1976, pp. 19-25.

TRANSPARENCIES

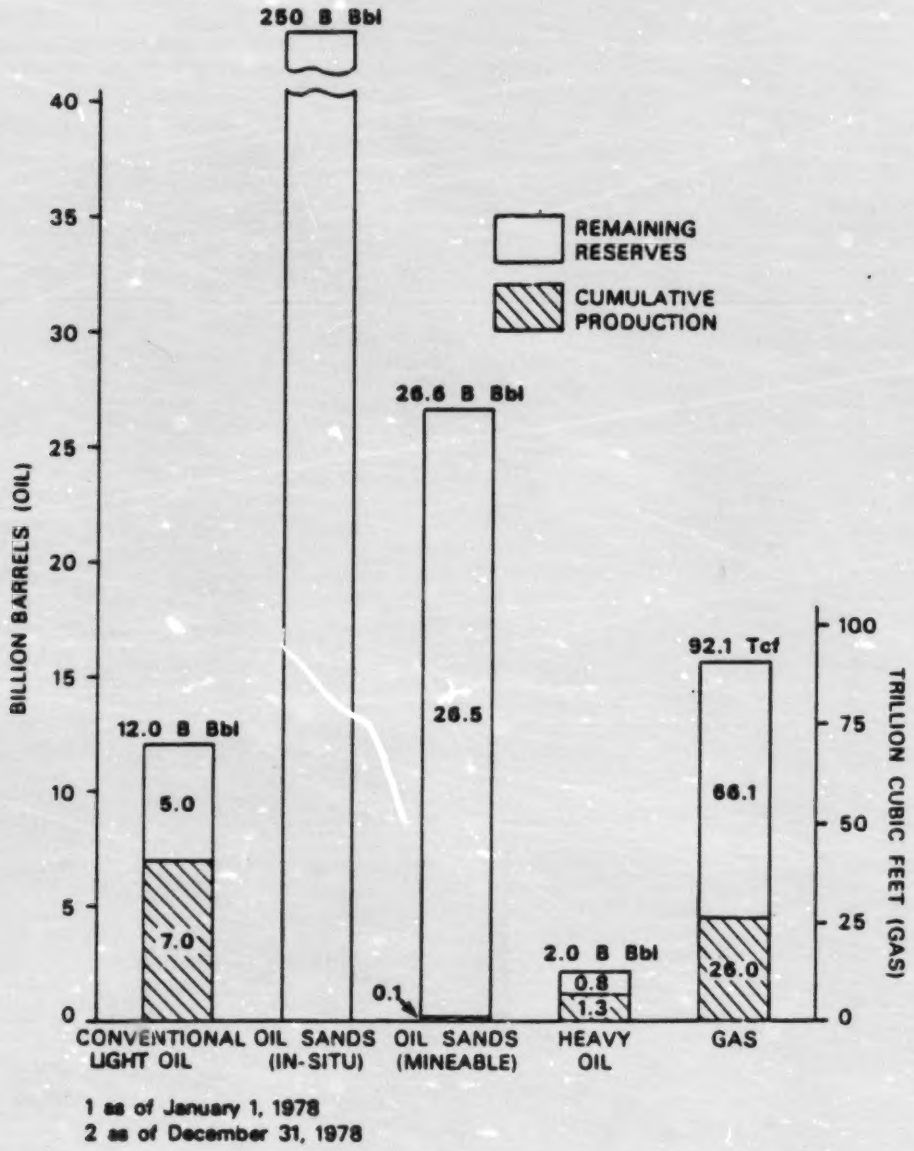


Where oil and gas may be found--the sedimentary rock areas of Canada.

Source: All About Oil. Imperial Oil Limited. Out of Print. Reprinted with permission.

B.C.
ALBERTA
SASK.
RAINBOW LAKE
ATHABASCA
PEACE RIVER
ATHABASCA
FT. MCMURRAY
SWAN HILLS
REDWATER
EDMONTON
COLD LAKE
LEDUC
BLOODBEND
PEMBINA
LLOYDMINSTER
SOFFRE
STETTLER
ELKTON
CALGARY
TABER
OIL SANDS & HEAVY OILS
MAJOR CONVENTIONAL RESERVES

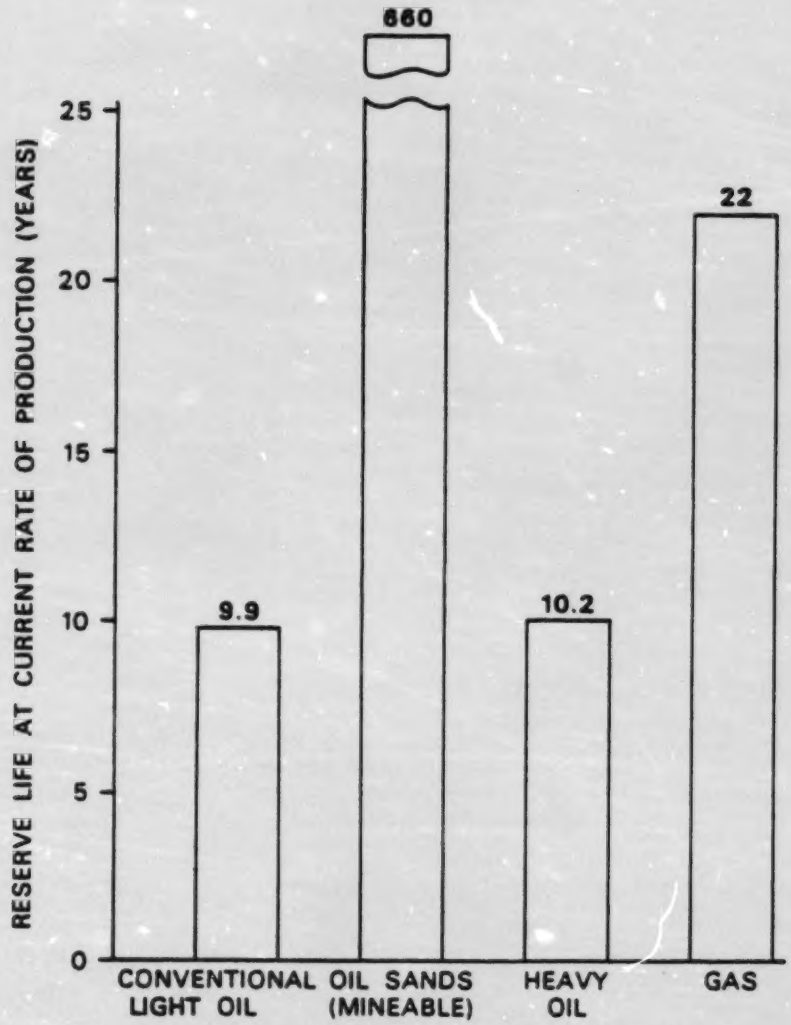
PROVEN RECOVERABLE RESERVES - OIL[1] & GAS[2]



1 as of January 1, 1978
2 as of December 31, 1978

Source: Canadian Oil and Gas Supply/Demand Overview, Energy, Mines and Resources Canada, November, 1979, Ottawa. Reprinted with permission.

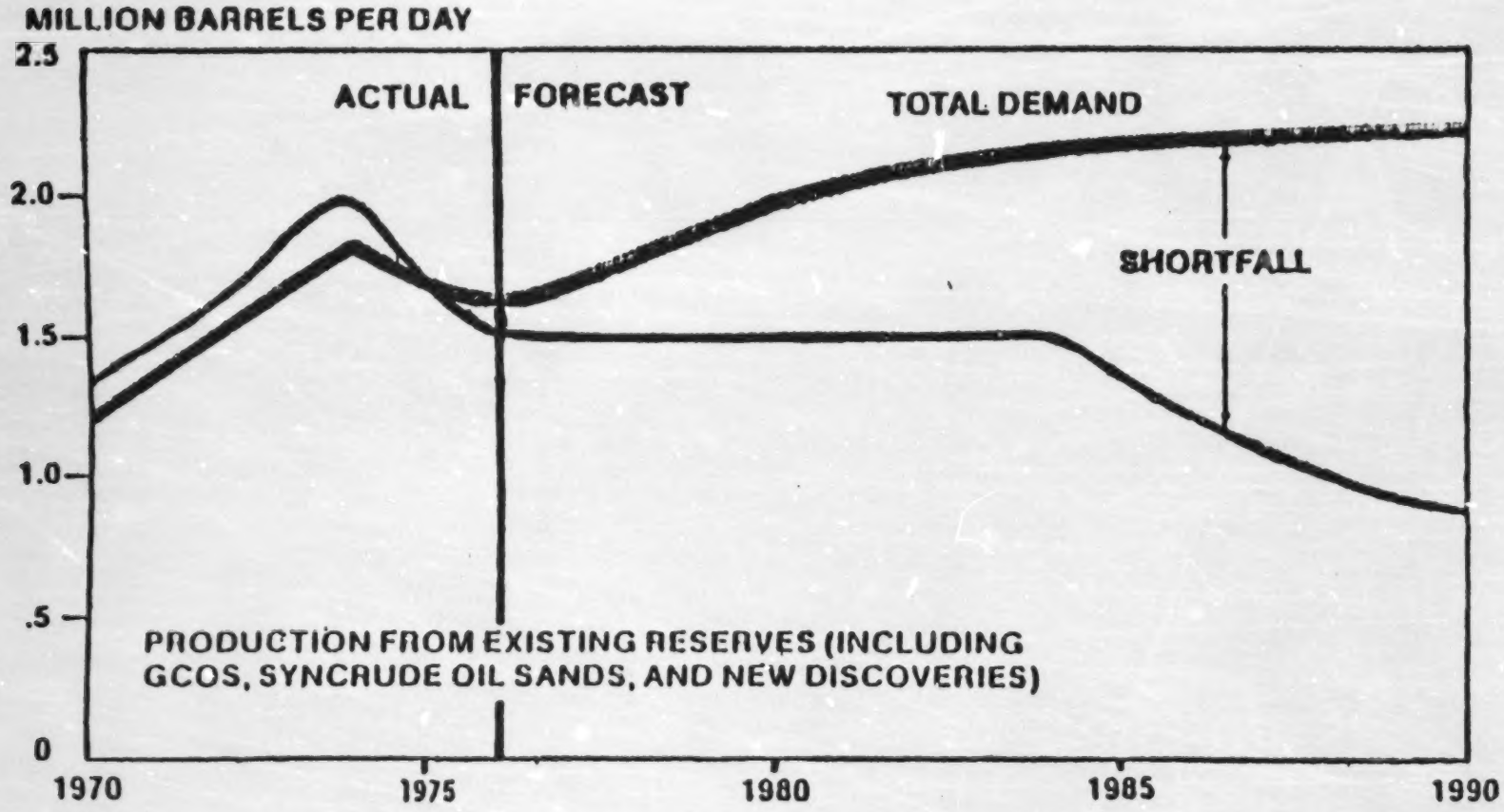
RESERVE/PRODUCTION RATIOS-OIL & GAS



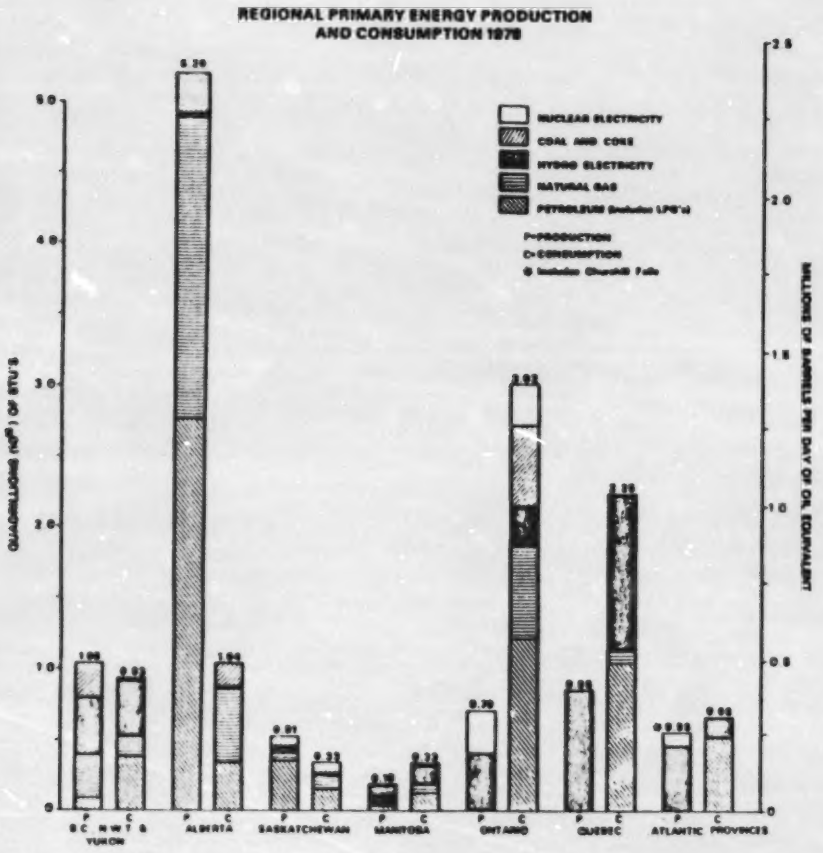
Source: Canadian Oil and Gas Supply/Demand Overview, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

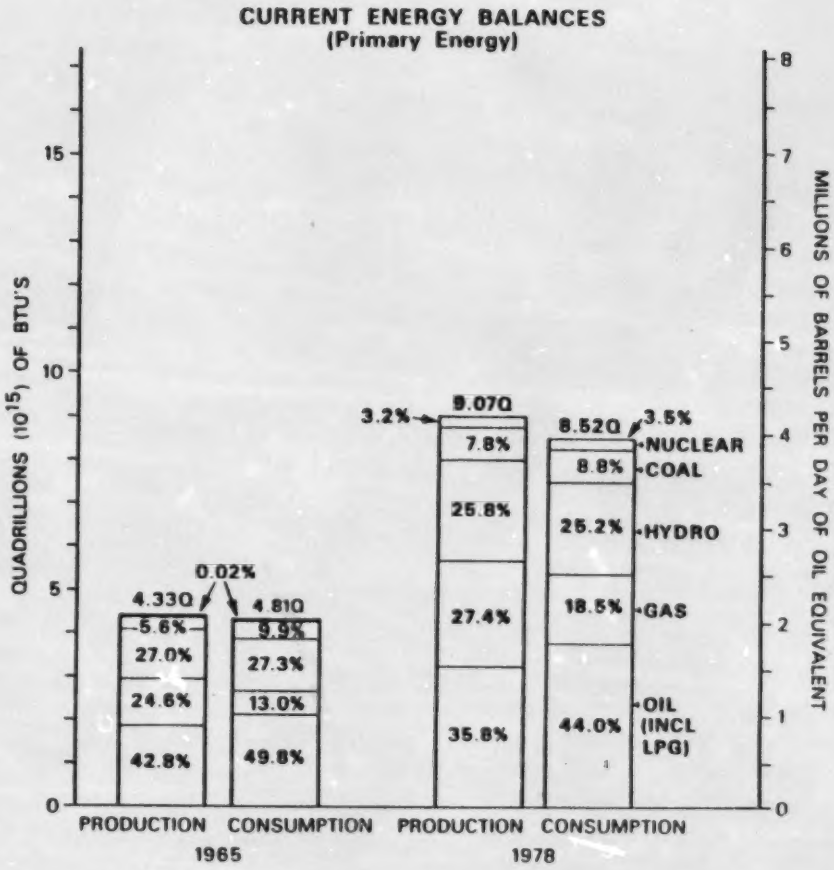
OIL DEMAND AND POSSIBLE PRODUCTION

In present producing regions of Canada

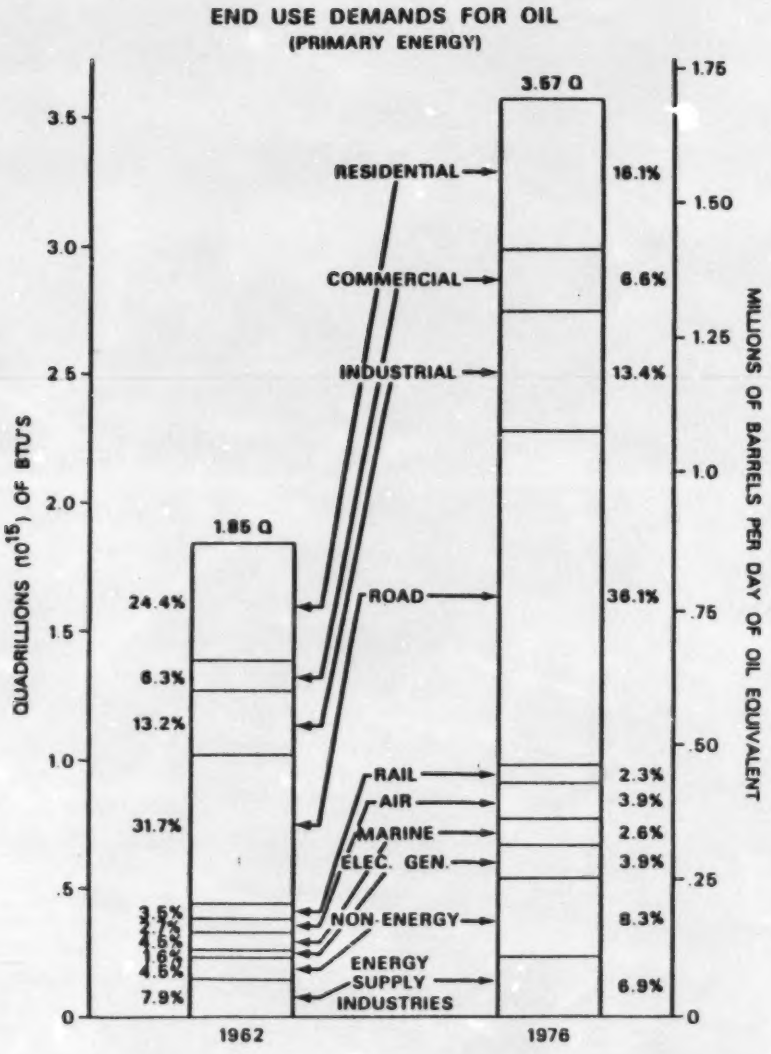


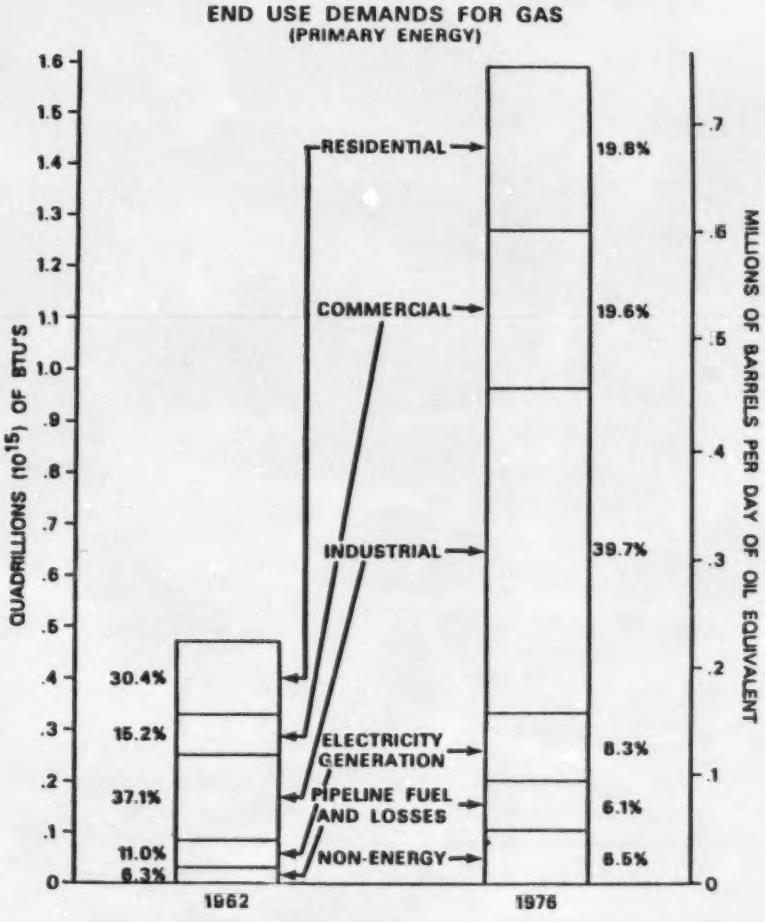
Source: Canadian Oil and Gas Supply/Demand Overview, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.





Source: Canadian Oil and Gas Supply/Demand Overview, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

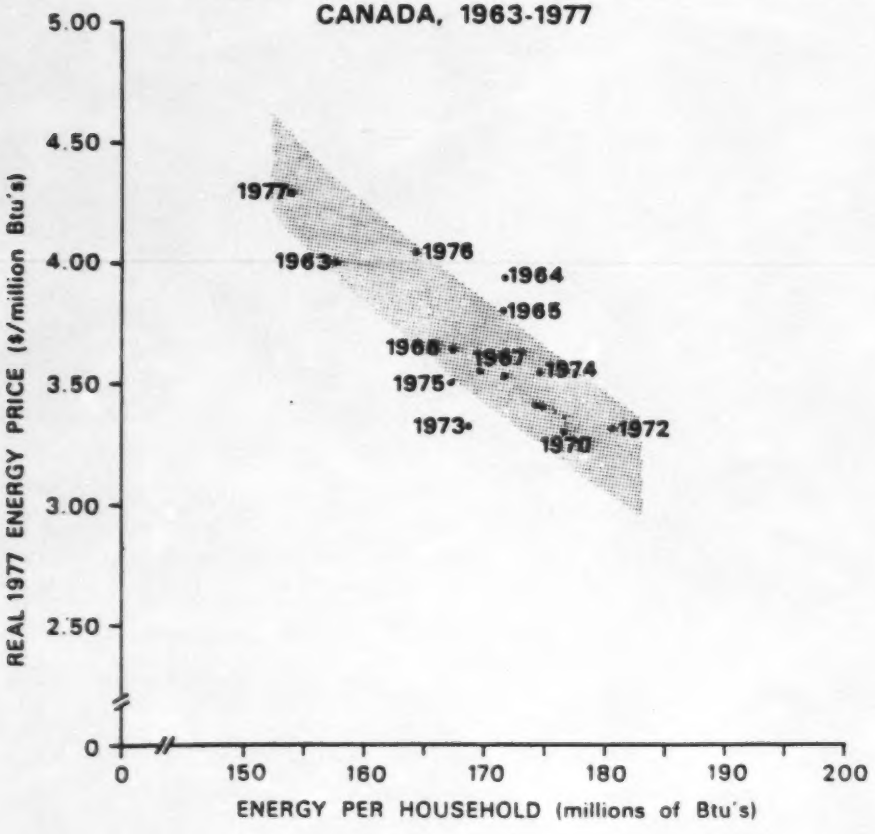




Source: Canadian Oil and Gas Supply/Demand Overview, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

Source: Canadian Oil and Gas Supply/Demand, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

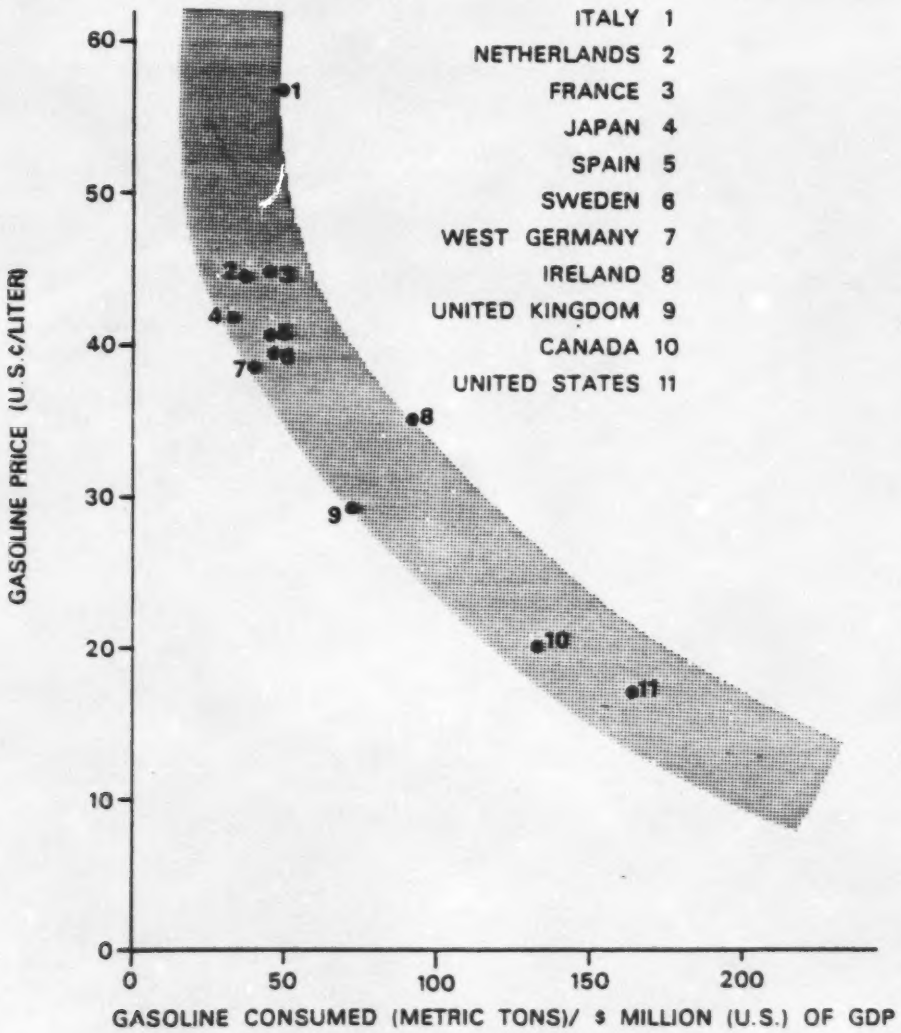
ENERGY PRICE RESPONSE IN THE RESIDENTIAL SECTOR
CANADA, 1963-1977



Note: The source should be read before the price-consumption is examined. Many variables could affect this relationship.

Source: Background to a New Energy Strategy, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

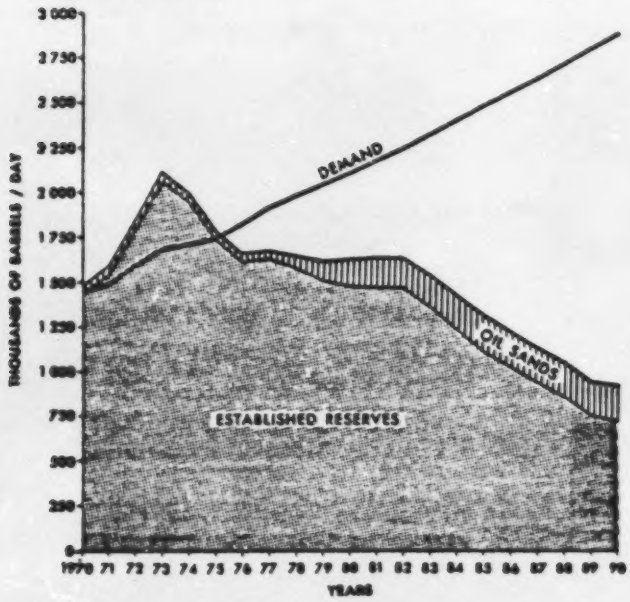
INTERNATIONAL COMPARISON OF GASOLINE PRICES AND GASOLINE CONSUMPTION IN THE TRANSPORTATION SECTOR 1977



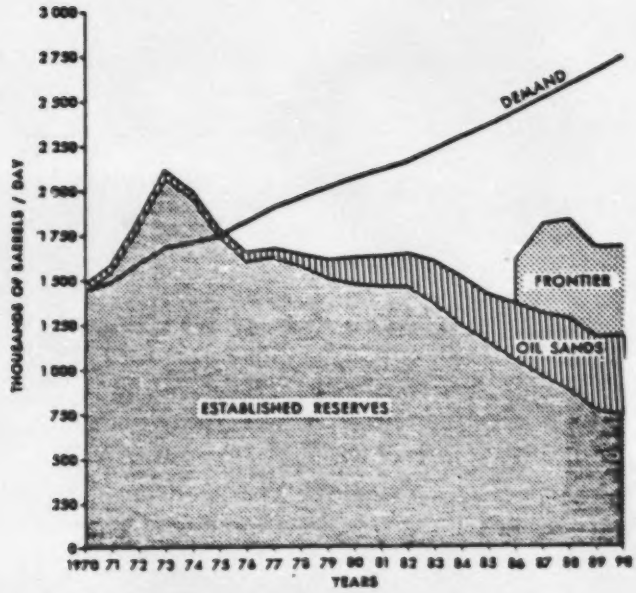
Note: The source should be read before the price-consumption response is examined. Many variables could affect this relationship.

Source: Background to a New Energy Strategy, Energy, Mines and Resources Canada, Ottawa, November, 1979. Reprinted with permission.

Domestic demand and availability: oil (1970-1990; low-price scenario).

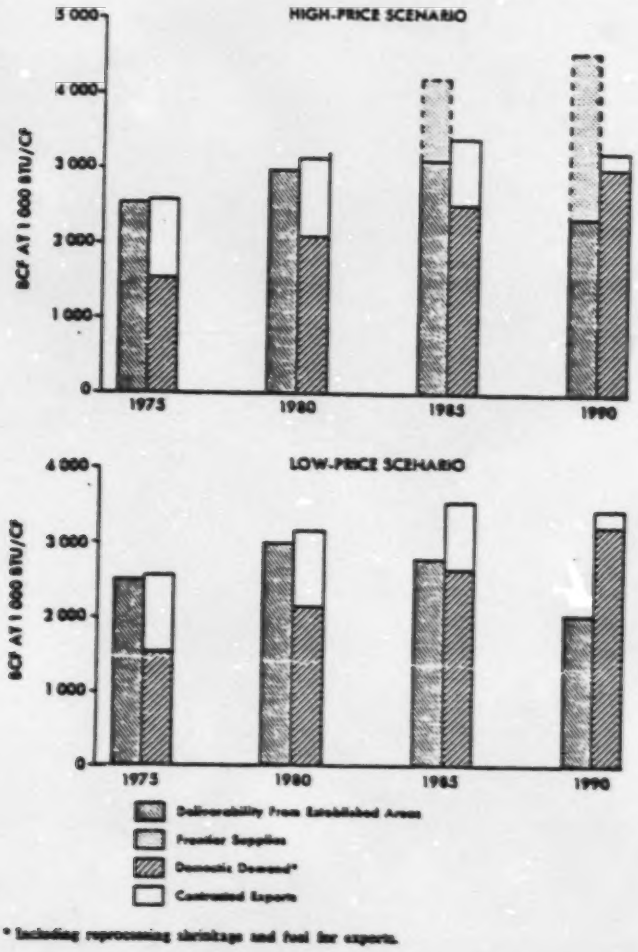


Domestic demand and availability: oil (1970-1990; high-price scenario).



Source: An Energy Strategy for Canada: Policies for Self-Reliance, Energy, Mines and Resources Canada, Ottawa, 1976. Reprinted with permission.

Demand and availability: natural gas (two scenarios).



* Including reprocessing shrinkage and fuel for exports.

NOTE: Since many assumptions are present in developing these scenarios, the source should be obtained and read before examining them.

Source: An Energy Strategy for Canada: Policies for Self-Reliance, Energy, Mines and Resources Canada, Ottawa, 1976. Reprinted with permission.

MANITOBA ELECTRICITY FACT SHEET

(October 1, 1980)

HYDRAULIC GENERATING CAPACITY

Utility	Station	Location	Number of Units	Capacity in kW	Initial Service
Manitoba Hydro	Great Falls	Winnipeg River	6	132 000	1923
"	Seven Sisters	"	6	150 000	1931
"	Pine Falls	"	6	82 000	1961
"	McArthur	"	8	56 000	1954
"	Grand Rapids	Saskatchewan River	4	472 000	1964
"	Kelsey	Nelson River	7	224 000	1960
"	Kettle	"	12	1 272 000	1970
"	Jenpeg	"	6	128 000	1977
"	Long Spruce	"	10	980 000	1977
"	Laurie River (2)	Laurie River	3	10 000	1962
Winnipeg Hydro	Pointe du Bois	Winnipeg River	16	72 000	1911
"	Slave Falls	"	8	68 000	1931
				3 644 000	

THERMAL GENERATING CAPACITY

Manitoba Hydro	Brandon	Brandon East	5	237 000	1957
"	Selkirk	Selkirk	2	132 000	1960
Winnipeg Hydro	Amy Street	Winnipeg	4	50 000	1924
				419 000	

GAS TURBINE GENERATING CAPACITY

Manitoba Hydro	Selkirk	Selkirk	2	25 000	1967

DIESEL GENERATING CAPACITY

Manitoba Hydro		22 sites	61	28 808	1958

TOTAL MANITOBA GENERATING CAPACITY 4 116 808

Source: Manitoba Hydro Publications, Winnipeg, 1980. Reprinted with permission.

Note: Manitoba Hydro's 29th Annual Report, 1980, provides additional material about sources of electrical energy, energy generation, purchases and sales, and hydro capacity and peak demand figures in kW.

POTENTIAL HYDRAULIC GENERATING CAPACITY

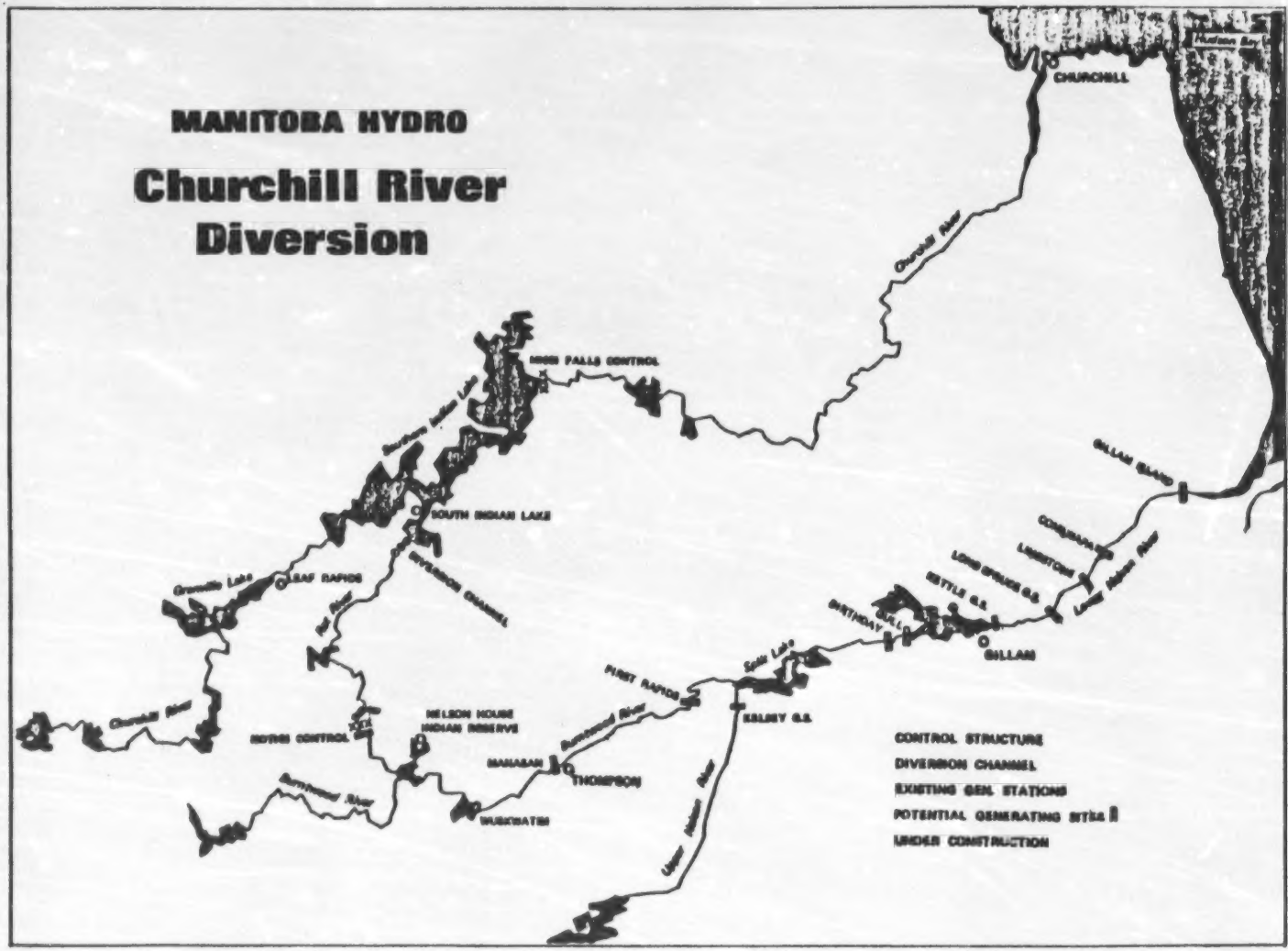
SITE	LOCATION	CAPACITY IN kW
Bladder Rapids	Nelson River	541 000
Kelsey (addition)	"	238 000
Birthday Rapids	"	585 000
Gull Rapids	"	523 000
Limestone Rapids	"	1 159 000
Conawapa	"	1 496 000
Gillam Island	"	691 000
Notigi	Rat River	85 000
Wuskwatim	Burntwood River	255 000
Manasan	"	191 000
First Rapids	"	195 000
Granville Falls	Churchill River	145 000
TOTAL UNDEVELOPED POTENTIAL		6 104 000

STATISTICS

(year ending March 31, 1980)

Customers: 444 000
Firm load: 12 847 million kW.h
Firm Peak (January 8, 1980): 2 519 MW
Exports: 7 131 million kW.h
Nelson River DC transmission: 12 688 million kW.h
Generation: 20 820 million kW.h (99.4% hydro)
DC transmission: ±450 000 volts

Source: Manitoba Hydro, Winnipeg. Reprinted with permission.



Source: Manitoba Hydro, Winnipeg. Reprinted with permission.